International Catholic University

Philosophy of Nature

William A. Wallace, O.P.

1st Lecture: Fundamental Concepts

- 1. Historical Notes
- 2. How We Know Things
- 3. Intellectual Knowledge
- 4. Basic Types of Concepts -- Natural Concepts
- 5. Mathematical and Metaphysical Concepts
- 6. Science and Philosophy
- 7. Logical Concepts
- 8. The Predicables
- 9. The Categories
- 10. Scientific Reasoning
- 11. The Demonstrative Regress

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- 3. Matter as Nature
- 4. Form as Nature
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3rd Lecture: Nature's Powers and Natural Kinds

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4th Lecture: Nature's Property -- Motion or Change

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- 8. The Subjects of Action and Reception
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5th Lecture: Nature's Measures -- Place and Time

- 1. The Concept of Place
- 2. Aristotle's Definition of Place
- 3. Place in the Universe, Old and New
- 4. The Concept of Space
- 5. Voids and Vacuums
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6th Lecture: Nature's First Unmoved Mover

- 1. Aquinas's *Prima Via*

- 2. The Motor Causality Principle
- 3. Validity in the Present Day
- 4. Three Instances of Local Motion
- 5. Efficient and Material Causality
- 6. Aquinas's Own Objection
- 7. Nature's First Unmoved Mover

Reading Assignments and Review Questions

Course Requirements

Students who are taking the course for academic credit will be expected to meet the following requirements:

1. Reading and studying the six lectures, and understanding the diagrams that accompany them. This is the primary requirement for the course, and will be the basis on which students will be examined at the end of the course.

2. Associated with these lectures are review questions that will enable the student to focus on the more important matters touched on in the lectures. Answering them as one proceeds through the course will be an excellent preparation for the final two-hour exam. Examiners who prepare this exam will draw on these questions in various combinations, while allowing some room for individual choices. (For example, the exam may be composed of six questions, from which the student need answer only four. Again, a question on a given topic may have several parts, only one of which need be answered by the student.)

3. Also associated with these lectures are additional reading assignments from the two textbooks being used in the course, *The Modeling of Nature: Philosophy of Science and Philosophy of Nature in Synthesis* (Catholic Univ. Press, 1996) and *The Elements of Philosophy: A Compendium for Philosophers and Theologians* (Alba House, 1977). These go into matters treated in the course in fuller detail, and will be especially helpful for meeting the second basic requirement of the course: a documented research paper on some topic in the philosophy of nature or a related topic in the philosophy of science.

4. The research paper should be type-written and between twelve and twenty pages (double-spaced) in length. It should be documented in the sense that it should include footnotes or endnotes, or parenthetical references inserted into the text, and should have a bibliography at the end. Topics for the paper may be taken from any matters treated in the lectures or in the reading assignments that accompany them. The point of the paper is to enable the student to go a bit

deeper into the subjects treated in the course, or to range beyond them into matters not treated explicitly in the course but still related to them.

5. The final grade for the course will be computed on the basis of 60% for the examination and 40% for the research paper.

How to Order This Course

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- 11. The Demonstrative Regress

Let me begin by introducing myself. I am William Augustine Wallace of the Order of Preachers, the Dominican Order, and I will be giving six introductory lectures on the philosophy of nature. I first learned philosophy of nature during my early studies in the Dominican Order, when I was then close to thirty years of age. That was after a naval career during World War II in which my main work was in science and engineering.

Now, it is common for people who study philosophy as their main interest to **begin** with a course on the philosophy of nature. This is a **difficult** beginning, particularly for those who already have the mind-set of modern science, as I know from experience. But I shall try to minimize that difficulty by showing the harmony that can exist between the philosophy of nature and modern science. I will also be using examples drawn from science wherever this is possible.

The main text I shall use is my own, *The Modeling of Nature: Philosophy of Science and Philosophy of Nature in Synthesis*. It was published by Catholic

University Press in 1996. To supplement this I will draw on one of my earlier books, *The Elements of Philosophy*, published by Alba House in 1977. This is essentially a compendium of all the philosophy articles in the *New Catholic Encyclopedia*, of which I was the editor for philosophy. It would be desirable to have access to the fifteen-odd volumes of the *New Catholic Encyclopedia*, but this is not necessary for the course.

1. Historical Notes

Philosophy of nature can make claim to being the oldest branch of philosophy. Perhaps that is a reason why students of philosophy start with that discipline. It began in the fifth century before Christ when Ionian philosophers, notably Thales of Miletus, speculated about the basic stuff of the universe -- **matter** in its most primitive form -- which the Ionians identified with the nature of things. A different approach was that of the Greek philosopher Plato, who saw **form** as distinctive of various natures. Plato postulated ideal forms -- existing in some heaven apart from earth -- in which he thought earthly forms somehow participated. It was Plato's student **Aristotle** who, in the fourth century before Christ, took Plato's forms from the heavens and put them into things, maintaining that that is where forms really exist. For Aristotle, both **matter and form** satisfied his idea of nature. He explained this teaching in a work called the *Physics* (*Phusika* in Greek, *Physica* in Latin). This gets its name from the Greek word *phusis*, translated into Latin as *natura*, which is the origin of our English word "nature."

Aristotle's *Physics* is one of the most durable works in the history of philosophy. It occupied the attention of the Greeks until the sixth century of the Christian era, and then was studied by the Muslims until the twelfth century. It took on new life in the thirteenth century, in the universities of the Middle Ages and the Renaissance, where it was required of all students. Indeed, this requirement lasted well into the seventeenth century. Not surprisingly Aristotle's *Physics* provides the core teachings I shall be explaining in these lectures. They do, of course, require development and exemplification in terms of discoveries made since the seventeenth century, with the rise of modern science.

To show the correspondence between the titles of my lectures and the matters treated in the eight books of Aristotle's *Physics* I employ my first schema. I shall be using graphical aids such as this throughout my lectures to illustrate the points I am making. These are available as diagrams to those taking the course for credit. Many of these figures are from *The Modeling of Nature*, though generally with numbers different from those in the lecture series. This is **Fig. 1.1**, not found in *Modeling*:

Lecture Title	**Aristotle's Physics**

1. Fundamental Concepts	Book I
2. Nature: The Inner Dimension	Book II
3. Nature's Powers and Natural Kinds	Book II (plus *De anima*, etc.)
4. Nature's Property: Motion or Change	Book III
5. Nature's Measures: Place and Time	Books IV through VI
6. Nature's First Unmoved Mover	Books VII and VIII

Reading Aristotle's **text**, even in English translation, is **difficult**. But if you have the time and energy I would suggest that you try to read along in his text as we progress through the lectures. I would recommend the translation with commentary of **Hippocrates Apostle**, published by the Peripatetic Press of Grinnell, Iowa.

2. How We Know Things

Aristotle begins the *Physics* with the cryptic statement that in natural philosophy we must proceed from what is more known to us to what is more known to nature or is more knowable in itself. Unpacking that statement will enable us to explain a few concepts relating to the **theory of knowledge** that are indispensable for our enterprise.

What Aristotle means by this statement is that we gain knowledge of nature from our senses or from sense experience, the type of knowing that is more obvious to us. But a deeper knowledge is also possible for us through our minds or our intellects, which enable us to transcend the knowledge of individuals provided by our senses. Our intellects are capable of grasping the natures of things as they are in themselves, through **universals**. Universals are less obvious to us, but with their aid we can go beyond the surface appearances of things as presented by our senses.

In Aristotle's theory of knowledge we attain intellectual knowledge through sense experience, for with him nothing is in the intellect that was not first in the senses. But **sense knowledge** for Aristotle was not as simple as it might first appear. Actually it is attained in two stages. The first stage is provided by our sense organs -- the eye, the ear, the nose, the mouth, the skin -- called **outer senses** because they are on the periphery of our bodies. When properly stimulated, each of these organs produces within us a **sensation** proper to the particular sense. These are the sensations of sight, hearing, touch, taste, and smell. The second stage then complements our outer senses by other senses we have in the interior of our bodies, called **inner senses** to distinguish them from the outer senses. The organs for these senses were not easily identified by the Greeks, but we now know that they are lodged in our brain and nervous system.

In a simplified view, the inner senses may be seen as made up of three components, the **central sense**, the **imagination**, and the **memory**. What is common to all three is that they are concerned not with a **sensation**, as are the outer senses, but with what I shall call a **percept**. A percept is nothing more than a unified sense image, a composite of the sensations produced by the outer senses. It is generated by the first of the inner senses, the **central or unifying sense**. This receives sensations and integrates them into a singular composite representation. In doing this it forms the percept, and the process by which it does so is known as **perception**.

For example, in sense experience I perceive an apple. This is an individual large, red, cold apple. All of these sensations, and possibly many others, are incorporated into the single percept whereby I perceive the particular apple.

Two other inner senses are **imagination** and **memory**. Once I have perceived an apple it is possible for me to reconstitute the elements that entered into its percept and, in the apple's absence to **imagine** the apple. I may imagine it as it actually was, or I may embellish it in fanciful ways, imagining it, for example, as a gold apple. Alternatively, I can recall the particular percept as it was in a past time, doing so through my memory, and in this way **remember** the apple.

As we use these three inner senses we build up what is called **sense experience**. This is nothing more than the accumulated memory of all the percepts we have experienced in our lifetime -- a huge storehouse of information on which we may draw with our intellects.

3. Intellectual Knowledge

Intellectual knowledge is quite different from sense knowledge, whether this derives from the outer senses or the inner senses. What the **intellect** does is work on our sense experience and extracts from it various intelligible aspects of things, telling us, in effect **what** things are. Put simply, it does so by focusing on the **percept** and extracting from it a universal that is called the **concept**. The intellect does this in two stages: first, by **illuminating** the percept in a particular way, and second, under this light, by **abstracting** from the percept its intelligible content. A percept, as already explained, is a **concrete** and **singular** image of the thing perceived. The concept, as opposed to this, is an **abstract** and **universal** representation that furnishes us with an **idea** of what we have perceived.

To return to our example of the apple, the percept of a particular apple is a composite image incorporating many sensations, such as would be found in a large, red, cold apple. Under the illumination it itself provides, the intellect considers the percept of that apple and leaves aside its particular size, color, temperature, etc. From what is left it forms a universal concept of apple. This is what we might call "appleness," whatever it is that that object has in common with other apples. The concept of apple is abstract because it is abstracted from the particulars of sense knowledge. It is universal because it grasps the nature of apple, essentially what we mean when we call the object perceived an apple.

Once we have grasped a concept -- and we do it all the time throughout our lives -- we are able to apply that concept to **all** objects we may perceive that share the same nature, in this case to all apples. This is what it means to say that the concept is a **universal**, it is a "unit" related to many "others" (a *unum versus alia*) that share the same meaning or intelligible content.

We may summarize what we have covered thus far by reference to our next schema, **Fig. 1.2** (p. 133 of *Modeling*). This is a much simplified diagram that illustrates the process of **concept formation**. On the far left is the external object, the real apple as it exists by itself independently of my knowing it. When properly illuminated and situated the apple affects my sense organs, identified in the first box on the left as "Outer Senses," and produces one or more sensations in them. These stimuli are then transmitted to my "Inner Senses," as shown in the next box, by signals sent to the brain through the central nervous system. There the central sense integrates the sensations received from the outer senses into a composite image known as a percept. Through this percept I perceive the object as "this large, red, cold apple."

Finally, my mind, shown in the last box on the right as the **intellect**, works on this percept to generate the concept. It does so in two stages. First it illuminates the percept to render it intelligible to my mind in a particular way. Second, under this illumination it extracts the intelligible content from the percept and gives birth to the concept. The first stage of the process, **illumination**, is produced by the natural light of the intellect when attending to percepts. The second stage, **abstraction**, is the way the intellect naturally effects a transition from singulars to universals. The percept, as we have already said, is "concrete and singular." The concept, by way of opposition, is "abstract and universal." Other terms for a concept are an idea or a meaning. In general we have in our minds as many concepts as we know words whose meaning, or the idea they convey, we correctly comprehend.

4. Basic Types of Concepts -- Natural Concepts

The process we have just sketched is an over-simplified explanation of how concepts are generated by the human mind. By the time students come to study the philosophy of nature they have obviously attained considerable experience of nature. Their minds, one might say, are chock full of concepts. I refer now to **every-day experiences**, where conceptualization is done naturally and effortlessly, just as easily, for example, as other natural processes such as breathing and digesting one's food. (Admittedly there are some abstruse matters that are difficult to conceptualize, such things as "entropy" and "geodesics," for example, but we are not concerned for the present with conceptualizations of this type.)

Let me make a start here, however, at classifying concepts, and begin with the types that can be understood simply on the basis of ordinary experience of the real world. A basic way of classifying concepts is in terms of the two processes whereby they are formed, already identified as illumination and abstraction.

We begin with the process of abstraction. To abstract is to pull out, or to extract, one or other intelligible content or meaning latent in a percept, leaving aside everything else that may be present in it. This abstractive process can yield various degrees of abstractness, depending on how the percept is illuminated by the intellect so as to leave aside various material aspects imbedded in the percept. Three orders or degrees of abstraction are generally enumerated. These suffice to differentiate concepts into three basic types, namely, **natural** concepts, **mathematical** concepts, and **metaphysical** concepts. Each of them we now consider in turn.

in order to

Natural concepts are important for us, since these are the type that are studied in the philosophy of nature. Natural concepts are associated with the **first order or degree** of abstraction. In this type of abstraction the intellect leaves aside only the individual and concrete aspect of the percept, that associated with the "this" of the percept. Up to now we have been considering "this red apple" as a percept. Here let me add a different percept, "this lead ball," assuming that we have perceived a little ball made of lead just as we have perceived a red apple. When we leave aside the "this" in these two cases, we come to the universals of "apple" and "lead," and are no longer tied to the particular apple or lead before us. "Apple" is the fruit of an apple tree, any and every apple, not merely the one we are perceiving. Lead is a metal, the eighty-second element in the periodic table, and again, any and every lead, not merely the lead we are considering.

What happens in this type of abstraction is that we grasp a **meaning** that is common to all classes of objects that share the properties of apple and lead. The concepts formed all imply some reference to **sensible matter**, that is, to matter that falls under our senses, but they abstract from **individual matter**, they leave aside all individual and distinctive attributes. The resulting abstraction is called natural or physical abstraction. It is employed in our ordinary discourse as well as in natural philosophy.

5. Mathematical and Metaphysical Concepts

Mathematical concepts are more abstract than natural concepts for the simple reason that more matter is left aside when they are conceptualized. Consider, for example, the perceptual basis for expressions like "three apples" and a "lead ball," and then the concepts of "three" and "sphere" that may be abstracted from the apples and the ball respectively. "Three" and "sphere" are mathematical concepts. They do not refer exclusively to any group of three or any individual sphere, but rather to all classes of objects that share that number or geometrical shape. Nor do they contain any reference to sensible matter. The "three" we conceptualize contains no reference to the apples, the sensible objects from which it is abstracted. It merely indicates a group of units that are only imaginable. Similarly "sphere" does not connote that the object known is composed of lead or wood or rubber. It merely indicates a body composed of continuous quantity, an imaginable or **intelligible matter**. Its matter, if you will, is made of pure extension, not matter that exhibits sensible qualities associated with lead or wood or rubber.

Metaphysical concepts, finally, have more in common with mathematical concepts than with natural concepts. They are, in fact, the most abstract of all. They are separated from matter entirely, for they include in their understanding no reference whatever to individual, sensible, or intelligible matter. Examples of such concepts would be "being" and "existent." The concepts of "being" and "existent" express an intelligible content that is found in apples, lead, and mathematical objects, since all of these are beings and existents in some sense. So characterized, metaphysical concepts are very general and apply to **being as such**, not merely to objects that exist in sensible or intelligible matter. They apply to whatever "is" in any way whatever, including things that are completely immaterial and incorporeal, such as God and spiritual substances.

When concepts are distinguished on the basis of their abstractness or degree of separation from matter, it is relatively easy to identify the objects studied in the philosophy of nature. A natural philosopher is not concerned with the entire range of being as such, as is the metaphysician. Nor is the natural philosopher concerned with quantified being as this is studied by the mathematician. The natural philosopher is concerned with the objects of ordinary experience, objects that exist in matter as it is perceived by our senses, what we call **sensible matter**.

One of the characteristics of such matter, as we shall see, is that it is always capable of undergoing **change**. Thus we can say that the natural philosopher studies **changeable being**, not **quantified being** or **being as such** -- the proper concerns of mathematicians and metaphysicians. And since **motion** is a kind of change, we can also say that natural philosophy is **the science of moveable being**, the type of being that can be changed and that undergo motions or mutations of various types.

At this point let me summarize what we have covered so far by sketching a preliminary typology of concepts as shown in **Fig. 1.3** (p. 140 of *Modeling*). The entries to the left of the double line pertain to the perceptual order. They designate extramental objects as they are perceived by the senses, basically through sensations and then through perceptions, as schematized in the two boxes to the left of the diagram on Fig. 1.2. The entries to the right of the double line, on the other hand, represent concepts. Thus they refer to the contents of the intellect box on the right of the diagram. In the middle column concepts are arranged vertically according to their order or degree of abstraction. A description of the kind of abstraction involved is then found in the column on the right.

ngoài tâm trí

6. Science and Philosophy

I have already mentioned the term "science," so let me make some preliminary remarks about science and how it relates to philosophy. Before the seventeenth century, for one studying **nature** the expressions **natural science** (Lat. *scientia naturalis*) and **natural philosophy** (Lat. *philosophia naturalis*) had exactly the same meaning. What **science** meant in those days was certain and unrevisable knowledge of objects, based on the **causes** that make the objects be what they are. The same definition applied to **philosophy**, for it too was regarded as certain knowledge of things based on their **causes**. In the case of **metaphysics**, the causes that are investigated turn out to be **ultimate causes**, and so this most generalized branch of philosophy seeks the deepest causes or explanations of everything that exists. But other branches of philosophy are more restrictive in their concerns, and that is why natural philosophy is concerned only with the causes of material substances, not of being as such.

tông quát hóa

Since the seventeenth century this concept of science has gradually eroded, so that few scientists of the present day would say that their science was **certain knowledge through causes**. This does not mean that scientists have given up their search for causes. One of their most frequently asked questions is "why" a particular phenomenon occurs. But science has now become so complex that it is rarely possible to give a definitive answer to that question.

bi xói mòn, bi an mòn

Again, modern science has changed its emphasis because of two features that are now its dominant characteristics. One is its use of **mathematics** and **measurement**, the other is its extensive use of **experiment**. The first, the use of measurement, means that modern science focuses almost exclusively on the quantitative aspects of things and **neglects many qualitative characteristics** that are revealing of their natures. The second, the use of experiment, means that modern science makes extensive use of **hypothetical reasoning**, and such reasoning rarely yields conclusive results.

luong

chât

At the end of the twentieth century, therefore, the **mind-set** of the modern scientist is not the same as that of the natural philosopher. Obviously they have

tu duy

different concerns and different methods of investigation. This does not mean that their two disciplines are incompatible, or that a person trained in both disciplines would not be able to coordinate their findings into a meaningful synthesis. But one cannot presume at the outset that the modern scientist and the philosopher of nature have similar objectives in mind in their reasoning processes.

7. Logical Concepts

Thus far we have discussed three kinds of concepts -- natural concepts, mathematical concepts, and metaphysical concepts. These are all concepts drawn from the **real world** by various degrees of abstraction and so we refer to them as **real concepts**. Real concepts are formed in our intellects, but they are **concepts of things** that exist outside our intellects and they enable us to grasp the natures of such things.

hóa ra, thành ra

Not all of our concepts, it turns out, are real concepts. Many of the concepts that exist in our intellects are not concepts of things but are **concepts of concepts**. Since **logic** is the science that studies "concepts of concepts" we call them **logical concepts**. Our primary focus, of course, is on the study nature, but to study nature we also have to acquire some knowledge of how our minds work when handling concepts. So we must now make a brief detour into logic.

Our first contact with logical concepts probably came when we studied **grammar**. Grammatical concepts are a special type of logical concept. Let us assume that we have grasped the concepts of apple and red, and then form from them the proposition or sentence, "The apple is red." Now let us reflect on that sentence from the viewpoint of the grammarian, and formulate two additional sentences: "Apple is the *subject*" and "Red is the *predicate*," indicating by these new words the place of "apple" and "red" in the sentence "The apple is red." In doing this we have formulated two new concepts, "*subject*" and "*predicate*." What we mean by this is that, in the sentence "The apple is red," the words "apple" and "red" stand in different relationships to each other, that, namely, of being the *subject* and the *predicate* of the sentence. The apple and the redness exist outside my mind as real objects. Subjects and predicates, of course, do not. They exist in my mind when I reflect on the structure of the sentence I have formulated, but apart from that they have no independent existence in the way that the apple and the red do without the sentence.

thuc hien; giu vung

Logical concepts, like real concepts, are universals, but they are universals of a special kind. The most important logical concepts are of two types: **predicables** and **categories**. Predicables are referred to as **modes of predication**, whereas categories are referred to as **modes of being**. Each of these types requires fuller explanation. You might wish to refere here to my *The Elements of Philosophy* for greater detail.

8. The Predicables

The **predicables** are five in number, usually enumerated as genus, species, differentia, property, and accident. **Genus** is the universal said of many things that differ in species, in answer to the question "What is it?" For example, one might say of human beings and brutes that they belong to the same genus, since all of these species fall under the genus of "animal." **Species** is the universal said of many things that differ only in number, in answer to the question "What is it?" For example, "man" or "human" are the species in which Plato and Socrates belong. This is the species of all humankind, containing as it does all individuals that share in human nature. (You will notice right away that the logician's use of genus and species is different from that of the biologist. Taxonomy in modern science requires many more groupings of natural kinds than those of genus and species, but these suffice in a general way for logical purposes.)

The next predicable, **differentia**, is predicated as the qualitative part of the nature of things that differ in number but also in species. Thus we say that a human being is "rational," for rationality is what differentiates the human species from all the species of brute animal. The final two predicables, property and accident, then indicate further specifications with regard to species themselves. **Property** in the strictest sense is the universal said of a species as belonging exclusively, necessarily, and always to that species and its individuals. An example would be "scientifically teachable," since only humans are capable of learning a science or other intellectual discipline. (Property is also used in looser ways, particularly in ordinary speech, but here we focus on the strictest meaning.) Lastly, **accident** is the universal said of a species as belonging contingently to the species and its individuals. "White" as said of humans is a predicable accident, since it does not pertain to the essence of being human to belong to the white race.

Reflecting on the five predicables, we might see that they reflect different aspects of the notion of **universality.** Universality is found more properly in **essential** predicates than in those that do not indicate the essence of the subject. Of the essential predicates, the **genus** is more universal than the **species**, and so these predicates are given first as **substantial** predicates. After them comes **differentia** as a **qualitative** predicate. And finally we have **property** and **accident** as predicates that are yet more distant from the essence of the subjects to which they are being attributed.

9. The Categories

The categories differ from the predicables, as already said, as designating **modes of being** rather than **modes of predication**. There are ten basic modes of real being, which were called categories by Aristotle. The first of these is substance, and other nine are quantity, quality, relation, location, time, situation, vestition, action, and reception. These are the basic or ultimate genera into which real entities may be classified.

As modes of real being the categories are not merely logical entities. They have a direct connection to reality in the sense that what they categorize is real. On the other hand, when something is so categorized it takes on a logical relation, and in this way takes on the character of a universal. There is nothing merely logical about an individual's being a substance, but to say of substance that it is a category is to say that we conceptualize it as a universal. On this basis philosophers distinguish between first substance and second substance. First substance is the individual being as it exists in itself; second substance is substance as it exists in the mind as a universal. The same idea could be applied to the remaining categories.

dam nhiem

Substance, then, is the first category, and substance is unique in that it exists in itself. The remaining nine categories share in common that they are **predicamental accidents** and exist in another, that is, not by themselves but in a substance. Thus substance is what is most basic and independent in existence. It "stands under" (*sub-stans*) and sustains accidents in their being and itself is a source of activity.

chính ban ngã cua mình

The first idea we gain of a substance is our very self. Each of us is a substance. I am aware that I now am, and have been, the same being over the entire course of my life. All of my accidents have changed, and yet I have remained the same. And I easily recognize that you are substances too, and so are plants and animals, and stones and minerals, and the various chemical elements.

Of the remaining categories for the time being I shall mention only three, quantity, quality, and location, for these are most important for the study of motion. **Quantity** is the accident by which a substance is said to be large or small, or to have part outside of part, or to be divisible into parts. It answers the question "How much?" (*quantum*). There are two kinds of quantity, discrete quantity, as in number, and continuous quantity, as in magnitude or size and extension.

Quality is the accident by which a substance is said to be of a certain kind (*quale*). The question "What kind?" can be answered in many ways, and so there are various species of quality. Now I focus attention on only two: sensible qualities and powers. **Sensible qualities** modify a substance insofar as it is capable of affecting the senses. On their basis we can identify sensible matter, that is, matter discerned through its color, heat, sound, taste, and odor. **Powers**

are the abilities and capacities of substances to initiate activities of various types. These are distinctive of various natures, as we will see in our next lecture. A nutritive power is found in plants, for example, motive powers in animals, reasoning power in humans, and so on.

As accidents, quantity and quality are absolute and intrinsic to a substance. The remaining accidents are said to be relative and extrinsic because they indicate a way in which a substance is related to something outside it. **Location** is one of these relative and extrinsic accidents. It answers the question "Where?," telling how a particular substance is related to place or space. Change of place is called "local motion." When I go from "here" to "there" I change my place, and this is one of the most obvious motions I can undergo.

With this we have now completed our exposition of concepts. Let us return to our earlier typology of concepts and update the diagram by presenting a **fuller typology of concepts**. This is given in **Fig. 1.4** (see p. 255 of *Modeling*). Again, all the entries on the left of the vertical double line pertain to the perceptual order and so designate extramental objects that are perceived by the senses. The entries to the right of the double line, on the other hand, represent concepts. These are now shown as being of two types, real concepts and logical concepts. The real concepts, as before, are arranged vertically according to the three degrees of abstraction. The logical concepts are also arranged vertically into three groups: grammatical concepts, predicables, and categories. Their vertical ordering does not match that of the degrees of abstraction. It indicates only that these are logical universals formed by the mind in its attempt to put order into its real concepts.

10. Scientific Reasoning

With these tools in hand we can now proceed to a final topic that is important for a philosophy of nature, that of scientific reasoning in the strict sense. By this I mean reasoning that is able to attain **certain and irrefutable** knowledge. This is the type of knowledge Aristotle called **science** (Gr. *episteme*, Lat. *scientia*), and which he sought in a work closely related to his *Physics*, namely, his *Posterior Analytics*. In that work he named the process through which science is attained **demonstration**, and this in turn was for him a special type of **syllogism**. So we have to explain the notions of syllogism, demonstration, and science if we are to have a grasp of what Aristotle meant by scientific reasoning.

We begin with a brief overview of **methodology** in the science of nature as this was viewed by Aristotle. The science he was seeking was **causal knowledge**, but he recognized that causes in nature are frequently hidden from us. Natural science is thus different from mathematics. Mathematics can begin with causes and principles that are easily grasped -- the definition of a triangle, for example.

Not so in the study of nature. Normally in nature we are presented with effects that are grasped by our senses, and our intellects are challenged to discover the causes of these effects.

tiên nghiêm

In reality, of course, causes come first and effects follow from them. So we say that the cause is **prior** and the effect is **posterior**. These two words, prior and posterior, are used to describe the two types of reasoning that are used in the science of nature. One is reasoning that proceeds **a priori**, that is, it starts from what is prior, the cause, and reasons to its effect. The other is reasoning that proceeds **a posteriori**, that is, it starts with what is posterior, the effect, and reasons back to its cause. And what Aristotle was saying is that in the science of nature, the order of knowing is usually the reverse of what happens in reality. We must **begin** with *a posteriori* reasoning to discover causes from their effects, and only when we have uncovered the causes can we reverse the procedure and **later** reason *a priori* to explain their effects.

hâu nghiêm

Thus scientific method in the science of nature normally proceeds in two stages, the first involving *a posteriori* reasoning and the second *a priori* reasoning. Some philosophers would describe the first stage as a process of **induction** and the second stage as a process of **deduction**. There are also other ways of characterizing this twofold movement of the mind, and these are indicated on my next schema, **Fig. 1.5**. This shows the two processes, on the top the first going from effect to cause, below it the second **regressing** or going back from the cause, when it has been determined, and using it to explain the effect. In view of this regressing, the twofold reasoning process is called by Aristotelians the **demonstrative regress**.

11. The Demonstrative Regress

Note on the left of the figure that the starting point is **effects**. These are usually **observations**, and they begin with **singulars** that are perceived by the **senses**. The first process employs *a posteriori* reasoning and it concludes with the discovery of **causes** or **explanatory principles**. These, we shall see, are not singulars but **universals**, and they are grasped not by the senses but by the **intellect**. Basically they are what we shall call **natures** or **definitions**. When we have grasped these, and this requires some additional work, we can embark on the second process. This employs *a priori* reasoning or deduction and it uses the causes or natures or definitions we have arrived at, all universals, to return to the observations we now fully recognize as effects, and understand them in terms of the factors that make them be what they are.

The work that intervenes between the ending of the first process and the beginning of the second process is what I call an **intermediate stage**. Aristotelians refer to this as a "work of the intellect" (Lat. *negotiatio intellectus*) or one of "mental examination" (Lat. *examen mentale*). This activity is difficult to explain in the abstract and is best seen through the use of an example. I shall use one given by Aristotle himself in the *Posterior Analytics* (I,13).

His example is the proof that the moon is a sphere from the obvious fact that it exhibits phases. The basic argument is that the moon (the **S**ubject) **is** a sphere (the **P**redicate) **because** it exhibits phases (the **M**iddle term). We may write the argument in the form of a **syllogism**:

A body that exhibits phases (M) is a sphere (P)	M is P
The moon (S) is a body that exhibits phases (M)	S is M
Therefore, the moon (S) is a sphere (P)	S is P

Now, for Aristotle, this is an *a posteriori* argument and a **demonstration**. Then, if one is sure that the moon's spherical shape is **really** the cause of its exhibiting phases, one can turn the demonstration he has given into an **a priori** demonstration simply by interchanging its middle term and its predicate. If we do interchange these terms we obtain the following syllogism:

A sphere (M) exhibits phases (P)	M is P
The moon (S) is a sphere (M)	S is M
Therefore, the moon (S) exhibits phases (P)	S is P

This entire argument may be formulated as the **demonstrative regress**, which is diagramed in **Fig. 1.6** (pp. 304-305 of *Modeling*). A person who grasps the force of this demonstration can be said to have **scientific knowledge** of the moon's having phases. One who does not/will have only probable knowledge or **opinion** about this particular phenomenon.

FIGURES

Fig. 1.1 The Lectures as Related to Aristotle's *Physics*

Fig. 1.2 The Process of Concept Formation

Fig. 1.3 A Basic Typology of Concepts

Fig. 1.4 A Fuller Typology of Concepts

Fig. 1.5 Methodology in the Science of Nature

Fig. 1.6 The Demonstrative Regress

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International Catholic University

Philosophy of Nature

2nd Lecture: Nature -- The Inner Dimension

- 1. The Concept of Nature
- 2. The Causal Model
- 3. Matter as Nature
- 4. Form as Nature
- 5. Nature as Agent
- 6. Nature as End
- 7. Cognitive Agents
- 8. The Inner Dimension
- 9. The Individual Natural Body

In our first lecture we sketched some fundamental concepts that are necessary for beginning the philosophy of nature. Our focus was on the theory of knowledge -- how sense knowledge differs from intellectual knowledge, how we form universals through a process of concept formation, and then the various types of concepts we attain through different degrees of abstraction. We explained that the philosophy of nature considers concepts that always involve some relationship to sensible matter, and that in this respect its concepts differ from those studied in mathematics and metaphysics.

We also explained the difference between the real concepts studied in natural science, mathematics, and metaphysics, and the type of concept studied by the logician. We referred to these as logical concepts, or concepts of concepts. Our detour through logic enabled us to explain what is meant by the predicables and the categories, giving brief definitions of each. We also talked briefly about how a proposition is formed by joining concepts as a subject and a predicate, in the form "S is P."

Finally we explained the concept of science as this was understood by Aristotle and how it appears in diminished and less rigorous form in modern science.

Scientific knowledge for Aristotle is certain knowledge through causes. The science of nature, for him, poses a special difficulty because nature's causes are generally hidden from us, whereas its effects are apparent to us through sense knowledge. So, in the science of nature, we must begin with what is more known to us, the sense knowledge of effects, and proceed from this to what is more known to nature or in itself, by an intellectual grasp of their causes.

1. The Concept of Nature

The title of this lecture is "Nature -- The Inner Dimension." This is the same as the title of the first chapter in *The Modeling of Nature*, where the topic is more fully explained. What we will be considering here is really the **subject** of natural science or philosophy of nature, namely, nature itself. We add to this the expression "the inner dimension," to convey some of the difficulty of grasping precisely what nature is. A thing's nature is not something readily apparent on the thing's surface. A special intellectual effort is required to grasp the concept of nature and to understand it in its full meaning.

A first approach to the concept is to see the world of nature as what is experienced when one goes into a primeval forest or gazes on a starry night into the depths of space. The natural is then perceived as opposed to the **artificial**. It is what is free from human effort, what comes into being and runs its course without benefit of man's assistance or influence.

Another sense of the natural differentiates it from the **forced** or the **violent**. The forced and the violent are done **from without** or by coercion. The natural comes **from within** the subject being studied. In this way of speaking, things have natures that are the sources of the activities they originate and so are peculiarly their own.

outside

composed of

Putting the two senses together, we may describe the world of nature as what is capable of coming into existence apart from human influence and as made up of things that have within themselves **natures** or **internal sources** of their distinctive activities. **Examples** of things with natures are minerals, plants, and animals, chemical elements and their compounds, planets, stars, and galaxies. All of these come into being and pass away, they are all **changeable** in one way or another. Yet they enjoy periods of relative **stability** during which they respond to, or interact with, objects around them.

To say of something that it is lead, or a geranium, or a horse, is to specify its nature. We humans have the capacity to grasp a thing's nature from its appearance and from the way it acts and reacts in various circumstances. To say of a horse that it is "a large mammal with solid hoofs that lives off plants" is to **define** its nature. It actually tells us **the meaning** of the word "horse" and how we can differentiate horses from other objects. And grasping that meaning is the work of the intellect, not merely the work of the senses. Natures are **universals**, objects of the intellect, as we explained in our last lecture.

To sum up: the nature of a thing is an **inner dimension** that makes the thing be what it is, that serves to differentiates it from other things, and that accounts for its distinctive activities and responses. We first grasp natures **in a general way** as we learn a language and attach meanings to words we use. We then develop and refine our understanding as we gain more information and experience about the objects we know. A horse trainer or a veterinarian obviously knows more about horses than does a youth who has little contact with them. Yet even the child who is able to say "That is a horse" grasps the same nature than does the expert, while doing so in a general and less specific way.

2. The Causal Model

The fact that a nature is only gradually disclosed in experience, and rarely is exhaustively understood, makes it especially suitable for study through modeling techniques. For our purposes a **model** is an analogue or **analogy** that promotes the gradual understanding of something that is not apparent in sense experience. When we encounter something new, we attempt to understand it by noting its similarities and differences with things that are familiar to us. A model enables us to do that. It enables us to use things we know, or at least think we know, to advance into the realm of the unknown.

The first model we introduce is a simple explanatory model known as the **causal model**. This takes its origin from the world of artifacts and is easily applied to the world of nature. It identifies **four factors** that are called **causes**, though not all in the same sense, since each functions in a distinctive way in a causal explanation. These four factors are usually identified as **matter, form, agent,** and **end**. More explicitly, matter becomes **material cause**, form **formal cause**, agent **efficient cause**, and end **final cause**.

When analyzing a chair on the basis of this model, we have no difficulty identifying the first two factors, **matter** and **form**. The matter is the **stuff** or material out of which the chair is made and which remains in it. An example would be wood, or, to be more precise, cherry or oak. The form is the **shape** or design imposed on the wood during the chair's making. Both of these factors are internal to the chair, they are **within it** and explain why it is what it is. On this basis we call matter and form **internal causes**.

The remaining two factors, **agent** and **end**, are external to the chair and serve to explain how the chair came to be. The agent is the **craftsman** who fashioned it from raw materials. The end is the **goal or objective** the craftsman had in mind when doing so -- say, to make a piece of furniture on which one can sit comfortably. Both of these explain the making of the chair. They are not **in** the chair in the same way as matter and form, and so they are called **external causes**. But once made, the chair retains a relationship to its maker. It also embodies the goal that motivated its making. And if it does that completely, it is said to be a **good chair**.

I am using graphical aids throughout these lectures that are available to those taking the course for credit. Many are these are diagrams found in my *The Modeling of Nature*, published by The Catholic University of America Press, in 1996. **Fig. 2.1** (on p. 24 of *Modeling*) provides a graphic illustration of this **causal model**. It makes use of a circle and three regular polygons to show how the four causes are distinguished and to detail the interrelationships between them. The **agent (A)** is shown as a triangle. It acts on the **matter (M)**, represented as a square. Its action brings forth the **form (F)**, which is diagramed as a circle. And the production of the form is itself the **end (E)** of the making process, which is shown as a hexagon. Thus all four causes are separate but interconnected: the agent (A) acting on the matter (M) and educing from it the form (F) as the end (E) of the process.

sinh ra, gây ra

In the artificial analogue this fourfold structure of causality is rather easily seen. An agent or efficient cause (the craftsman and the tools used) worked on a particular kind of matter (say, oak) and shaped it into a form (that of a kitchen chair) that had a distinctive end (providing something comfortable to sit on, say, while eating).

Our problem now is to see how these same four causes can be uncovered in the order of nature and how, when uncovered, they provide us with an insight into the **inner dimension** of natural entities. By **natural entities I** mean substances that have natures that serve to explain their distinctive activities -- natural substances such as elements and compounds, plants, animals, stars, and planets. We must examine the **stuff** from which natural things are formed, how their **forms** differ from those of artifacts, the various **agencies** that produce them, and the ways in which they attain **ends** intended and achieved through nature's operations.

3. Matter as Nature

If the matter or material cause of a natural entity is the **stuff** from which it is made and remains in it, precisely what that stuff is invites clarification. The wood from which a chair is made is apparent on the surface. It may be seen, for example, as oak or cherry. Not so simple is identifying the material out of which an oak tree or a cherry tree is made. The same applies to an element such as lead, or an animal such as a horse. Is there **a basic stuff** out of which natural substances are made and that remains in them?

Philosophers and scientists have been pondering this question for some twenty-five centuries. The best answers have been obtained from studying the various changes natural substances undergo as they are generated out of preexistent materials or broken down into them. The earliest proposal was a **four-element** theory. In this theory the basic postulated entities were **fire, air, water**, and **earth**, and these were used to explain all terrestrial phenomena. To them were added a fifth element, a **quintessence** known as **aether**, to explain phenomena in the heavens. The result was a very durable explanatory scheme that lasted for twenty-four centuries -- all the way to the end of the eighteenth century.

dua vào, dem vào, mang vào

It was around 1808 that the **chemical** revolution brought in **hydrogen, oxygen, nitrogen, carbon**, and other substances as better candidates for elemental status. These provide the common answer given by those who have studied modern science -- : the **chemical elements** are the basic stuff of the universe. But the shortcoming of that answer becomes apparent as soon as we ask **how basic** this stuff can be. Put in another way, what is the stuff of which these elements themselves are made? And, if electrons, protons, and neutrons is our answer, well, what is the stuff of which they in turn are made? And so on. The jury is still out on **any final answer** to that type of question.

More will be said about the **material substrate** of natural substances in our next lecture. For now it may suffice to note that Aristotle spoke of the ultimate material component of natural entities as "**first matter**" or "**protomatter**" (Lat. *materia prima*. Gr. *hule prote*). He thought of it as a type of **conservation principle** that persists through all natural changes in the universe.

Somewhat unexpectedly science has come to develop a similar conception in recent years. No longer are scientists searching for one final particle that is the ultimate building block of the universe. Instead they are focusing attention on factors that are **conserved** in all the changes that take place in the world of nature. Probably the most successful factor they have unearthed to date is owed to Albert Einstein, the concept of **mass-energy**.

I shall be using mass-energy in these lectures to gain some insight into prime matter or **protomatter** as the **basic potential principle** underlying all changes in the universe. Both of these concepts are different from those of ordinary experience and are difficult to conceptualize. But no longer are we to think of matter as the passive and inert component of things it was previously thought to be. Rather it is a **potency** that lies at the base of the most cataclysmic upheavals taking place on our planet as well as those occurring in the remote depths of space.

disastrous, catastrophic

su bien dong dot ngot

4. Form as Nature

Returning to the causal model based on our artifact, the chair, we note that its form is intimately related to its matter. **Form** is the shape or figure the **matter** assumes when the chair is made, so that form becomes part of its being. Moreover, although the wood, say oak, was not always formed as a chair, as long as it was identifiable as oak it was always under one form or another. From this point of view **matter and form** are quite inseparable. This being so, one might think that both are equally unintelligible. Just as there is something mysterious about the basic matter of the universe, so one might think that form is unintelligible too. Not so! Though matter is to a large degree refractory to the human mind, form is surprisingly **intelligible**. It provides **a window** through which the world of nature is seen and through which many of the **natures** that inhabit it can be readily understood.

cuc ky, vô cùng

We can see this from the ways we speak about the **natural objects**, and not merely the artifacts, that fall under common observation. We are able to identify most of the **animals, plants**, and **minerals** with which we come in contact. We are also able to classify them in ways that show our awareness of the differences among them. Moreover, though many of these objects have a multiplicity of parts and are far from homogeneous in structure, we grasp them in a **unitary way** and ascribe **one nature** to them. It is this **formality** or **form** that we name and define as we become acquainted with the **natural kinds** in our environment.

How, then, may be characterize this **natural form** in a way that differentiates it from an artifact? Obviously the **shape** of a cow or a giraffe, even seen in silhouette, is a help in identifying it. In this respect it resembles the form of an artifact. But the shapes of organisms vary over a wide range from one individual to another, and even in one individual throughout time. This is true despite the fact that the natures underlying the shapes remain the same. And similar statements may be made about most of the quantitative and qualitative attributes that are found in natural substances.

dê cho

So as to differentiate shapes and other accidental forms from the type of form that gives unity to a nature, philosophers label this a **natural form** or a **substantial form** -- a form that underlies its attributes and make it **an enduring substance**. Changing attributes and properties they then refer to as **accidental forms**. These are forms that modify the substance in various ways. Accidental forms may vary in degree, or in presence and absence, without affecting the basic character of the substance.

It is this natural form or substantial form that we apprehend when we grasps the **nature of a thing** and attempt to define it. Then it becomes a **universal** as described in our last lecture. It is given in sense experience, but it requires an intellectual process of abstraction -- the first degree of abstraction -- to be apprehended by us. When the universal is grasped, whether it is the nature of applicable

lead, copper, oak, mosquito, or kangaroo, it becomes appicable not only to this or that lead, copper, oak, etc., but to each and every instance of them. Were this not so, it would be impossible for us to have universal knowledge of the world of nature, and *a fortiori* any science of nature.

The simplicity and universality of the natural form should not obscure the many attributes and activities that derive from it and of which it is the **inner source**. To say that a horse is a mammal, for example, signifies that it belongs among vertebrates that nourish their young with milk secreted from glands of a special type. The entails a complex **organism** with structures and organs that function in interrelated ways to assure the well-being of the whole. Much more will be said about the ways in which activities originate within such natural agents in our next lecture. For now it need only be mentioned that the **unifying form**, no less than the **underlying matter**, is the inner source from which all such activities ultimately spring.

What has been observed thus far is applicable to natures found in **common experience** and readily apprehended by our **senses**. Special problems are posed by entities in the microcosm and those in the remote depths of space. Whether things such as quarks and black holes even exist, or whether they have natures in the same sense as the animals, plants, and minerals we generally know, are problems for the **philosopher of science**. The important point to note, however, is that we cannot **start** with such entities to construct a philosophy of nature. In our discipline we must proceed from the more known to the less known, not the other way round. And natural form is intelligible to us and provides the necessary starting point for the philosophy of nature.

5. Nature as Agent

Now we come to the third explanatory factor in our causal model, the **agent** or **efficient cause**. In the making of the chair we pointed to the **craftsman** as the principal agent. This was the case of one natural substance, a man, acting on another natural substance, say oak, to transform the oak into a useful artifact. The craftsman had the capability to make a chair because of **motive powers** lodged within his nature. These powers can serve to explain how he could be an efficient cause in the production of the chair. As it turns out, human beings are natural organisms that possess **many powers** and capabilities, and so they can serve as a paradigm for the investigation of agencies in nature.

It is natural for humans to think and to will, to speak and to write, but these are activities of the mind rather than of the body. The production of material artifacts, a work of the body, are also characteristic of humans. The example of chair-making can be extended indefinitely as one ranges through all the constructive, mechanical, and industrial arts -- the feats of engineering, the products of technology in our century. Man is a **powerful agent** who acts,

ky thuat ?
khoa cong trinh ?

directly and indirectly, on the substances around him, appropriating them and transforming them in countless ways to suit his needs and desires.

Similar instances can be adduced in the **animal** and **plant** kingdoms. Beavers build dams, birds build nests, and spiders build webs. In all these natural activities they use or affect objects with other natures to the benefit of **themselves** and their **species**. Animals give birth to young and plants bear seeds, thus serving as agents for bringing new organisms into the world. And through the balance of nature, fauna and flora convert chemical substances and direct solar energies to provide food and nutriment for a wide range of species. All living organisms, in their life processes, are so many **agents** that interact with their environment and produce changes in other things in the course of their development.

At the level of the nonliving, on the other hand, agencies are not so easy to identify. But modern **chemistry** has provided remarkable insights into the ways elements interact with each other to form compounds. Chemicals have **affinities**. Under proper circumstances they enter into combination with other substances, thus affecting them and in many instances giving rise to new natures.

Physical agents are frequently seen as exerting **forces** on objects and causing motions and changes of state in them. In this view, a force is itself an instance of an agent or **efficient** cause. Indeed, the use of the force concept in the physical sciences illustrates how pervasive agency or action is in the realm of the inorganic.

Physicists link forces with **energies and fields**, and these provide a further source of information about natural agents. Studies in high-energy physics yield **four major forces** that are believed to underlie all of nature's transformations. These are the gravitational force, the electromagnetic force, the strong force, and the weak force. They will be discussed in our next lecture. Each of them provides examples of ways in which the material components of the universe act on each other to produce the phenomena observable within it.

6. Nature as End

This brings us to the fourth and final factor in our causal analogue, the **end** or **final cause**. The Greek word for end is *telos*, source of our term **teleology**, and thus to the problem of teleology in nature. For Aristotle it was almost axiomatic that nature is teleological, that it acts for an end. In our day the problem takes on added importance because of the theory of evolution. If evolution is viewed as a natural process, does this not entail that it is a teleological process? Is not evolution **goal directed**, in the sense that higher and more developed species are not merely the result of chance but are somehow predetermined **by**

nature?

To answer this and related questions, it can be helpful to distinguish three different meanings of the word "end," not all of which apply equally to natural processes. The **first** and simplest meaning is that of **end** in the sense of **terminus**. In traveling from "here" to "there," the "there" is the end of the trip, where the traveler comes to rest. In falling motion, the motion terminates when the heavy object arrives at a center of gravity. In the domain of the living, growth terminates when the organism reaches a state of maturity. Fleas grow, but not to the point where they reach the size of elephants. They stop growing when they reach a size fixed by their nature. Chemical reactions "go," but they also "stop," for example, when hydrogen and oxygen combine to form a stable molecule in water. Some heavy elements break down radioactively, but not indefinitely. The breakdown of uranium, for example, terminates at lead. So nature is more than an inner source of change and activity. It is also the source of **permanence and stability**. When such stability terminates a natural process, whether inorganic or organic, it is the end of the process and as such its **final cause**.

A **second** meaning of end or goal adds to the idea of terminus the notion that it is somehow a **perfection or good** attained through the process. In some instances of natural change this meaning is easily verified, in others it is not. Clearly in cases of organic growth the end product represents a superior grade of being over the stage at which it began. It is also more perfect, in the etymological sense of the Latin *per-fectus*, as that which is thoroughly made and possesses no *de-fectus*, i.e., is lacking in nothing it should possess.

In **inorganic** changes it is difficult to see how a **compound** is better than an **element**, or how an element of higher atomic number is better than an element of a lower. Perhaps one should differentiate here between processes that are good for a **particular nature** and those that are good for **nature as a whole**. Elements are good in themselves, and sometimes act to preserve their own being, as when sulphur crystallizes and so preserves its identity. But compounds may better serve the needs of the organic world. Plants and vegetables represent a higher stage of being than complex molecules. Yet their stage is lower than that of the animals that eat them and incorporate them into their substance.

If this seems true in the observable order of nature, it would be even truer in **evolution**, if this is indeed the **work of nature**. The successive production of higher and higher types represents some kind of **progress** -- a greater good or perfection attained over time -- presuming that the later types are not mere freaks or chance occurrences.

7. Cognitive Agents

The **third** meaning of end is more specialized still. It adds to the notions of termination and perfection that of **intention** or **aim**. This serves to identify the type of final causality found in **cognitive agents**. **Animals** and **humans** are natural agents of this type. Many of their activities are planned or intended in advance and so can be seen as **end-directed** from the beginning. A person building a house or a bird building a nest must have in advance some notion of what is intended. Otherwise neither builder would know how to gather the materials. There is a difference, of course, between the bird and the human. The bird does its work by instinct and makes its nest in a shape distinctive of its species. Humans are not so limited and can generate the multiplicity of dwellings known throughout human history.

Much of the difficulty with teleology in nature arises from seeing all final causality as intentional or cognitive, and not differentiating the **cognitive** from the **terminative** and the **perfective.** Medieval thinkers gave expression to this mentality with the expression *opus naturae est opus intelligentiae*: "the work of nature is the work of intelligence." If by saying this one means that every natural agent is **consciously** aware of the goal at which it is aiming, there is little evidence that this is so throughout the entire order of nature.

Yet the word intelligence can take on a variety of meanings. Note the way we speak of **artificial intelligence** in the present day. Perhaps in that way of speaking one could say that the double helix is programmed to replicate in a certain way and so "knows" how to do it. Or again, an asteroid "knows" how to find its path through the solar system without performing the calculations we make to predict its path. In this sense, natural agents seem to **foreknow** what they aim to achieve and so implicitly substantiate the claim that nature acts for an end.

Such considerations open up the complexity and mystery of final causality in nature, analogous to those already uncovered in investigating other lines of causality. **Matter** and **form** are easy enough to grasp in a general way, and yet understanding **ultimate matter** and **unifying form** presents difficulties of great magnitude. Natural **agents** are pervasive in the universe and some are readily identifiable. Yet **cosmic agents** are largely hidden and so have escaped detection for centuries. **Final causes** exert their influence in terminative and perfective ways, yet they too give rise to serious problems. Is there an **ultimate goal** to which nature tends? Is there an **intelligence** behind its operations that organizes its matter and its agents so as to achieve that goal? To answer such questions properly would take us considerably beyond the scope of the philosophy of nature. But simply posing them may perhaps illustrate why the study of nature is a fruitful starting point for one who wishes to become a philosopher.

8. The Inner Dimension

From the outset of our discussion two different but interrelated **meanings** of nature have been touched on. It is now necessary to focus on one of the meanings to make precise the sense in which nature may be spoken of as an "**inner dimension**," serving to differentiate natural entities from those seen as artifacts.

The two meanings may be approximated by noting that one captures nature when the word is written with a **capital** "N," the other when it is written with a **small** "n." The first designates the **world of nature**, the universe untouched by man but of which he is a part, the object of his consideration when exploring a primeval forest or when gazing into the starry heavens. It is this sense of nature that leads one to think of the Author of Nature or of Mother Nature -- some overarching principle that puts order into a vast collection of individuals to make of them a **cosmos**, an awe-inspiring system of the world.

The second meaning of nature focuses on the **units** that enter into this world system. These are the particular **natures** found in the universe that enable things to be classified into **natural kinds**. Questions relating to nature in this second sense turn our thought **within**, to a consideration of the **intrinsic factors** that enter into the individual's composition. This is the sense of nature captured by the expression "inner dimension." It is this meaning that is our focus of attention for the remainder of this lecture.

We think of the inner dimension of natural substances as constituted by **matter** and **form** as these have now been explained. Both matter and form are clearly components of nature as **inner sources** of the properties and activities of substances themselves. But we have also touched on **agent** and **end** as types of causality that are proper to nature and its activities. Apparently these additional causes are not merely "out there" but also somehow "**inside**" or "within" the entities that make up the natural world. We must first address the problem of how our "inner dimension" is constituted not merely of material and formal causes but of efficient and final causes as well.

In **Fig. 2.1** we diagramed how four causes are involved in the production of an artifact. We used a **circle** and **three regular polygons** to show their distinction and the interrelationships between them. You will recall that an **agent** (A) acted on **matter** (M) and educed from it **form** (F) as the **end** (E) of the production. All four were seen as causes, separate but interconnected.

Let us consider now the analogous case whereby, in the order of nature and over a period of time, an **adult female squirrel** generates another adult female -- a mature organism of the same nature as itself. The agent here is the **parent squirrel** along with its partner's seed (A), the matter (M) is the **gametes** on which they work, actually parts of their substances, and the form (F) is the same in kind as their own, namely, the **form of a squirrel**. The offspring first appears as a zygote or embryo, but over a length of time it undergoes a growth or developmental process whose end (E) is the **adult squirrel**. The parents and their offspring thus share a **common nature**, even though their appearances will differ markedly over time.

This final situation may be diagramed as shown in **Fig. 2.2** (p. 26 of *The Modeling of Nature*), now labeled "the inner dimension." It aims to show that nature, while **primarily** constituted of matter (M) and form (F) as the **intrinsic causes** that make the substance be what it is, also incorporates **agencies** (A) and the **functions** for which they are programed (E), all of which can be modeled by the corresponding causes of an artifact. Each cause serves as a **determiner** lodged within the specific nature as such and, to this extent, may be regarded as part of its inner dimension. The natural **form** (F), to be sure, is the **dominant determiner**, for it is eminently intelligible. So intelligible, in fact, that it can be grasped, even by a youth, to serve as a **starting point** to unravel the remaining three causal factors. All four causes then **explain** the complexity of that nature and the manifold activities to which it can give rise.

The circle in Fig. 2.2 represents the **natural form** (F). The regular polygons then designate the other three causes, the **agent** (A) represented by the triangle, the **matter** (M) by the square, and the **end** (E) by the hexagon. The diagram is only schematic. Its purpose is not to represent natures in general but only the **particular nature** of a higher mammal such as a squirrel. Even then the nature shown is not individual but is common and specific, common to the parents and offspring of a family and to the squirrel species.

In this representation the **basic matter** (M) is its **nature**. For now let us call this the **mass-energy** of each organism, the co-principle within it that makes it a **material substance**, capable of **subsisting** as an individual, **initiating** various activities, and being **receptive** of them. The **natural form** (F) is also the organism's **nature**. This is even more the nature than the matter. It is a complementary co-principle, **activating** the mass-energy and **determining** the matter, contracting its potentialities, as it were, to being a **substance** of a **particular type**. It then **stabilizes** the substance in such being, **supporting** its distinctive **powers** and activities. Among these powers is the nature itself as an **agent** (A), as a source of activity that includes the ability to **replicate**, to produce another nature similar to its own through the reproductive process. And finally, when this new nature is produced as the **end** of the process (E), the same nature terminates the process and so may additionally be designated its **final cause**. Thus all four causes come to be **internalized** within the concept of nature, even though only the material cause and the formal cause are spoken of as internal causes in the strict sense.

9. The Individual Natural Body

Thus far we have been talking about specific natures, the universals that are associated with natural **species** of various types. There are additional problems relating to **individuals** of those species, which I must treat briefly under the title, "The Individual Natural Body." Our aim is to show how one may regard matter and form as internal causes, while allowing **agency** and **finality**, which are usually regarded as external causes, **also** to be lodged within the individual natural body.

The structure of the individual natural body is diagramed in **Fig. 2.3** (p. 27 of *The Modeling of Nature*). This shows that an individual natural body is a **composite** of substance and accidents. The substance of a thing is what enables us to locate it within a **species**, to tell what it is. The accidents of a thing are its **individuating characteristics**, and they enable us to recognize the thing as a particular individual of that species. The first composition is enclosed in double outline and labeled "substance." The second composition is enclosed in single outline and labeled "accidents and properties."

Concentrate first on the inner box, that of **substance**. As diagramed there, substance is shown as an inner core that is itself **composed**. The two components are both **essential** components, and they are **matter** and **form**. In our earlier diagrams we labeled these as M and F, but these letters are now replaced by PM and NF. **PM** stands for **protomatter**. **NF** stands for **natural form** or substantial form.

The **accidents** of a natural body are then shown in Fig. 2.3, arranged arbitrarily around the inner core. They are arranged into three categories: **quantitative**, shown in the diagram on the left of the inner core; **qualitative**, shown on the right of the inner core; and **relative**, shown beneath the inner core. The distinctive accident of the first group, the quantitative, is **quantity**, which is aligned with **protomatter** on the left of the diagram. The distinctive accident of the second group, the qualitative, is **quality**, aligned with **natural form** on the right of the diagram. The remaining accidents are then all grouped beneath the inner core in the middle of the diagram. Only two are shown there, **relation** and **location**, because of their bearing on the problem of motion.

Complete details on quantity and quality, and particularly how quantity is related to individuation and on how powers are qualities, will be found in *The Modeling of Nature*, pp. 27-31. Powers are substances' most **distinctive attributes**, because their numbers and kinds are the major indicators of the **various natures** that underlie them. How this is so will be the subject of our next lecture. It is also through powers that **efficient causes** and **final causes** are found operative in the world of nature. **Powers** solve the puzzle of how all **four causes** can be **internalized** within a natural body.

FIGURES

Fig. 2.1 The Causal Model

Fig. 2.2 The Inner Dimension

Fig. 2.3 The Individual Natural Body

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International Catholic University

Philosophy of Nature

3rd Lecture: Nature's Powers and Natural Kinds

- 1. Powers of Human Nature
- 2. The Modeling of Nature
- 3. Elemental Bodies
- 4. Modeling an Inorganic Nature
- 5. Protomatter -- The Ultimate Substrate
- 6. Iconic Models
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- 8. Chemical Composition
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- 10. Summary

We ended our last lecture with the notion of **powers**. We had made the point that powers are distinctive properties of substances that provide a direct insight into their **natures**. In this lecture we shall continue with this theme, focusing on **inorganic** or **non-living** natures. In so doing we shall develop further the concepts of **protomatter** and **natural form**. We shall also touch on a few topics relating to **quantitative** aspects of nature, and how the philosophy of nature relates to the modern sciences of **physics** and **chemistry**.

1. Powers of Human Nature

Of all natures in the universe the nature that is most intelligible to us is our own nature, **human nature**. We have a privileged insight into ourselves, and even before we study the **philosophy** of human nature -- as treated in Aristotle's *De anima*, for example -- we have some idea of **our own powers** and how they operate. Let me start with the **powers** that are distinctively **human**, therefore, for these can aid us in understanding the powers of other natures.

I am using graphical aids throughout these lectures that are available to those who are taking the course for credit. Many of the figures are found in my *The Modeling of Nature*, published by the Catholic University of America Press in 1996. If you have these, **Fig. 3.1** (on p. 134 of *Modeling*) provides a schematic diagram of the six generic powers found in a human being. These are shown in the diagram as parts of a stimulus-response model, with the **stimulus** represented by the **S** at the top left of the diagram, and the **response** by the **R** directly below it. The three boxes along the top of the figure are known as **cognitive powers**. They are, from left to right, the **outer senses**, the **inner senses**, and the **intellect**. We have already explained these powers and their operation in our first lecture. At that time we did not go into the other powers with which they are closely connected, which we now show directly beneath them along the bottom line. Known as **appetitive powers**, they are, from left to right, the **motor powers**, the **sense appetites**, and the **will**. The diagram as a whole, on this account, is entitled "Human Cognitive and Appetitive Powers."

The operations of these powers are indicated in the lower portion of each box. From left to right, when acted on by external stimuli, indicated by the letter **S**, the outer senses serve to explain our **sensations**. The outer senses next activate the inner senses, which produce our **perceptions**, and they in turn activate the intellect, from which come our **intellections** or **thought processes**. Then, continuing directly below the intellect but now proceeding in the opposite direction, from right to left, the will produces our **volitions** or acts of the will, the sense appetites our **emotions**, and the motor powers the **movements** of our bodily organs. The bottom line terminates on the right with the letter **R**, standing for responses and so completing our stimulus-response (**S-R**) model. These are the many activities we initiate in response to stimuli. And in so initiating them, we act as **agents** or **efficient causes**, and we achieve **ends** or **goals** that are the **final causes** of our activities.

From this simple diagram, therefore, we get the point of how powers can serve as **efficient causes** that have **final causes** built into their operation. Through the use of powers, therefore, we are able to incorporate both **agency** and **finality** in a nature's activities.

2. The Modeling of Nature

We now have enough information to make a synthesis of the three most important concepts we have developed so far, namely, **protomatter**, **natural form**, and **power**. We shall refer to this synthesis as a **model**, thus introducing the theme of our text, ***The Modeling of Nature***. Now the term "model" is used in science in many different ways. The model we shall be using I refer to as an **epistemic model**. By an epistemic model I mean an analogue or an analogy that conveys ideas or concepts that are not directly apparent in sense experience. Thus the aim of an epistemic model is to produce intellectual knowledge that is certain, which is what the Greek word ***episteme*** means. We have already used one such model in our last lecture when we presented our **causal model**. This new model is a further development of the causal model. I shall call it a **powers model**, because it makes use of distinctive powers to characterize the properties of different natures.

It is difficult to display **protomatter** in a flow chart or a circuit diagram such as we have used up to this point. But in the present day most people realize that there is more to matter than meets the eye. It has been said that matter has been "dematerialized" in our generation. What this means is that the ultimate matter can no longer be thought of little hard balls of stuff. Better to think of it as a **matrix**, an underlying principle that is conserved throughout all physical change. It is also a source from which all natural forms spontaneously emerge. In itself protomatter is like a kind of **potential energy**, nothing actual or determinate, but an indeterminate something that grounds every change and motion going on in the universe.

To convey this idea in my model I start with **protomatter** simply as a mathematical **point** at its center. Protomatter has no extension, no qualities in terms of which it can be known. Then, because of the intimate relationship between protomatter as a **potential principle** and natural form as its **actualizing principle**, I next show a series of concentric circles that radiate out from the center. The concentric circles are meant to suggest that **natural form** acts as an **energizing field**. What the field does is "expand" the protomatter, as it were, and **form** it into a substance of a particular kind. In other words, the natural form is a **substancing** form, one that determines protomatter to be a particular substance. And it brings with it not only existence, but also extension, bodily parts, and all the qualities **proper** to that substance.

The natural form, moreover, is a **unifying form**. It confers a unity on all the parts of a natural body and makes of them a functioning whole. It is a **specifying form**, making all of the components be and react in a way characteristic of the **natural kind** to which the substance belongs. And it is a **stabilizing form** that preserves the identity of the substance and **maintains** the unity of its components under external influences -- to the extent that this is possible in a changing world.

Thus we have incorporated both protomatter and natural form in our model. What are we now to do with **powers**? There is a simple solution. Since powers are actually powers of the natural form, we simply locate them as boxes or squares **within** the energizing field. For the moment I am interested in a **generic model** that will serve our needs later, and for this purpose four boxes will suffice. Let us now arrange four boxes symmetrically within the field. When we do so we have the **powers model** shown in **Fig. 3.2** (see p. 31 of *The Modeling of Nature*).

In this figure **protomatter** is labeled as **PM** and it occupies the point at the center of the model. The concentric circles or the "field" radiating out from PM we label **NF**, and this stands predictably for **natural form**. The four boxes within the field have no labels for the moment. We show them simply as cross-hatched, but later we shall identify them in specific ways. Notice that some of the boxes are fitted with **arrows** pointing away from the box or toward the box. The arrows represent the **actions** and **reactions** that are received from, or are received into, the particular power. They are indicators of **efficient causes** that act for particular **ends**, in ways we are about to describe.

3. Elemental Bodies

If nature, as described in our previous lecture, is the inner dimension, the source of characteristic **activities**, we can see right away the problem posed when modeling inorganic or non-living substances. As opposed to living things, **inanimate objects** have little activity that can serve to reveal the natures that are within them. They tend to be **inert**, and observation alone seems powerless to reveal any of their powers.

With so little to go on, the ancients concentrated on **sensible qualities**, on the ways substances affect our senses, as primary indicators of basic kinds. The various pairings of **active qualities**, hot and cold, with **passive qualities**, wet and dry, led them to regard **earth, water, air**, and **fire** as the four basic elements. To these they added the **motive powers** of gravity and levity to explain **up** and **down** motions, as these elements approached or receded from a **center of gravity**. This, they thought, could explain all the basic changes in the **terrestrial region**. For the **heavenly region** they had to add **aether** as a fifth element, a **quintessence** or *quinta essentia*. Its natural motion, for them, was **circular**, constant movement around a center, for this is how the celestial spheres appeared to move.

For present purposes we can recreate the inorganic powers implied in the Aristotelian system of elements in the diagram shown in **Fig. 3.3**. The two boxes in the top line took care of the major **alterations** observed on the earth's surface. That on the left, the **active qualities** of hot and cold, explained **heating** and **cooling**, whereas that on the right, the **passive qualities** of wet and dry, explained **dissolving** and **melting** processes. And the two boxes on the bottom line took care of all the **local motions** seen in the universe. That on the left, the **motive powers** of gravity and levity, explained **rectilinear** motions to and from its center, and that on the right, various **aether powers** associated with the quintessence, explained the **circular** motions seen in the heavens.

This theory, primitive though it was, had a long **history**, lasting over twenty centuries. It was really not replaced until the late eighteenth century, with the birth of modern chemistry. At that time **experimentation** and **measurement** was added to simple observation. Of special importance was the study of ways substances react to one another when placed in solution or in close contact. One of the earliest procedures consisted in isolating various substances in the **gaseous** state. It was found that as gases substances could be made to combine, and then precise measurements could be made of the **weights** and **volumes** that entered into combination. Repeated confirmation and analysis of such measurements throughout the nineteenth century led to an important discovery. Over ninety unit atomic weights were found in nature, one for each chemical **element**. And even vaster numbers of unit molecular weights, one for each chemical **compound**, were found in nature also. Unit atomic weights, by definition, had their counterparts in **atoms**, and unit molecular weights had their counterparts in **molecules**. Thus did the concepts of atom and molecule enter into modern chemistry.

By the end of the nineteenth century the **periodic table** of the elements had been basically completed. How molecules were structured out of atoms was then well understood. The twentieth century saw the **atom** broken down into its components, a **nucleus** surrounded by orbiting **electrons**. Then the nucleus itself was broken down, first into **protons** and **neutrons**, then into the large numbers of nucleons now being studied in high-energy physics. And out of all this work came a startling conclusion. All of the physical and chemical phenomena in the world of the inorganic could be explained in terms of **four basic forces**. These you have probably heard of in popular media, even if you have not studied them in a science class. They are know as the **electromagnetic** force, the **gravitational** force, the **weak** force, and the **strong** force.

4. Modeling an Inorganic Nature

With this we are in a position to update the Aristotelian model of an inorganic nature and bring it into the twenty-first century. In fact, all we need do is replace the four boxes of **Fig. 3.3** with the four basic forces of recent **physics**. These are the agencies through which elements and compounds, and even subatomic entities, are now known act on each other. All of the forces have **potentials** and fields associated with them, so it is a simple matter to make the transition to **powers** when labeling them. (The Latin term for **force** is *vis* or *virtus*, and both terms are usually translated into English as **power**.) So let us now revise the view presented in Fig. 3.3 and introduce its modern replacement, but incorporated in the context provided by the earlier diagram in Fig.3.2. We then have our next diagram, which we label as **Fig. 3.4** (p. 71 of *The Modeling of Nature*), "A Powers Model of an Inorganic Nature."

In the new diagram we have replaced the cross-hatched boxes of Fig. 3.2 with boxes containing the **four forces** of recent physics. The labels are now **EF**, for electromagnetic force, **GF** for gravitational force, **WF** for weak force, and **SF** for strong force. We have retained the **F** for force rather than using the **P** for power. But whether **F** or **P** is used, the idea is the same. We are attributing to the **natural forms** of non-living substances **powers** through which they act, analogous to the *vis gravitatis* (that is, force of gravity or power of gravity) that was attributed to them from the time of Aristotle.

In our figure, as previously, the protomatter (**PM**) is shown in the center. The natural form (**NF**) is the field, the series of concentric circles energizing the protomatter. Notice that the NF now bears the subscript "i" to designate it as inorganic, that is, a natural form of a non-living substance. And arranged symmetrically in the field are the four boxes designating the powers that are operative in inorganic substances.

At the top left, electromagnetic force explains chemical actions and reactions, indicated by the arrows attached to the box, going in both directions. These are associated with the **electrons** and **ions** that cause elements and compounds either to enter into combination or to break down into their components. At the bottom left, gravitational force is the associated with the **mass** of a body. By action and reaction, again indicated by the pair of arrows, it explains most of the phenomena studied in the science of **mechanics**, including gravitational interactions. At the top right, the weak force, again reciprocating, is useful when explaining various types of **radioactive** emission and absorption. And finally, at the bottom right, we have the strong force, also reciprocating, that **binds** nucleons together in the atomic nucleus and serves to explain nuclear reactions.

Inanimate substances with which we ordinarily come in contact, solids and liquids mainly, are characterized by **all four** forces or powers. In daily experience we notice only **weight** or other gravitational effects, but with some observation and experiment we can become acquainted with **chemical** changes and the agencies that produce them. We need more sophisticated equipment to gain knowledge of **radioactivity** and **nuclear** reactions. Yet the powers to produce them are present in **all** sensible substances and so should be regarded as part of their natures.

The four forces or powers give a **generic** understanding of non-living substance, but they do not provide information at a **specific** level. To move to this stage we must return to the essential components of **substance** itself, protomatter and natural form. Let us now do this, concentrating first on the matter and then on the form that determines it to be a particular **natural kind**.

5. Protomatter -- The Ultimate Substrate

Thus far we have proceeded on the assumption that atoms and molecules serve as **matter** for chemical reactions. We have also assumed that electrons, protons, and neutrons, the last two located in the nucleus of the atom, function as **material parts** when explaining radioactivity and nuclear reactions. These assumptions now require fuller investigation.

A fruitful path to pursue is to pose a question. If chemical substances are composed of **atoms** and **molecules**, and these in turn are composed of **electrons**, **protons**, and **neutrons**, what more can be said about the **stuff** of which all these are made? To push the inquiry further: if subatomic particles such as these are composed of yet **smaller** and **more elementary** particles, is there any **limit** to which one can go in seeking the matter of which everything is ultimately composed? This is the question of the **ultimate substrate** of natural processes, which we have identified with the protomatter of Aristotle.

Since the discovery of **radioactivity** at the end of the nineteenth century it has been known that certain chemical substances break down **spontaneously** into others of lower atomic weight, and in so doing emit particles and radiation of different types. Two of these particles have proved extremely difficult to detect. One of them is the **anti-neutrino**, a massless and chargeless entity possessing only what is known as "spin," and the other is the **W-particle**, a massive particle associated with the **weak force** that holds the neutron together, whence the "W" in its name.

in order to

Apart from radioactivity, it has long been realized that a very **strong force** is required to hold the components of the atom's nucleus, called **nucleons**, in stable positions. The very strength of this force requires massive equipment to break through it so as to study the structure of the nucleus. The huge **particle accelerators** of high-energy physics are what are used in this task. But rather than simplify the model of the nucleus, the investigations of nuclear physicists have produced precisely the opposite result. They have led to the discovery of **hundreds** of new **particles** and **anti-particles**, of which protons, neutrons, and electrons are merely special cases. Attempts have been made to cut through all this complexity, but without much success.

The best that can be done, apparently, is to say that there are **six** ultimate states of matter, **three quarks** and **three anti-quarks**, which combine in various ways to produce the particles acted upon by the strong force. **Quarks** themselves cannot be isolated, since they always recombine to maintain the appearances of known particles. Thus it is meaningless to inquire into their **structure** or to ask whether they are composed of more ultimate constituents. The search for a fundamental **ground** to all natural processes seems to end with them. Stated in another way, it ends with a number of **conservation principles** on which the quark hypothesis is based. These enable us to identify the particular features that will always remain throughout various nuclear reactions.

What I have said is, of course, not proposed as documenting the final stage of nuclear research. It does, however, lend strong support to a view of the ultimate substrate that the famous physicist, Werner **Heisenberg**, saw as going back to Aristotle's pure ***potentia***, his "first matter." For Aristotle protomatter is not itself a subsistent entity that is already formed. Rather it is an unformed and indeterminate something that it at the base of all substantial change. As the basic material factor, what it contributes to the coming to be of a new substance is its **potential.** And that potential is merely its ability to be **determined** by a specifying form to constitute an entity of a particular kind. Somewhat like the quark, protomatter is always "**confined**" within matter of some kind. It simply cannot **exist** by itself in isolation from a determining form. Better to think of it as a **principle** or a **cause** entering into the composition of a natural substance without being identifiable as a subsistent entity or complete substance itself.

6. Iconic Models

Having said this about **protomatter**, we can now take a closer look at its correlative principle, **natural form**. This is also a **principle** and a **cause**, but it turns out to be considerably more intelligible than protomatter. I shall approach its intelligibility by first introducing to you a model of a different kind from those we have discussed thus far. This new type of model is an **iconic** or **pictorial** model. Being a **sensible** model it is more easily grasped by us than the epistemic models we have already considered. But an analysis of a few iconic models will show that they themselves are only intelligible in terms of the **powers models** that actually lie behind them.

The first iconic model we present is the **Bohr model** of the atom. A simplified version of this model for the first **eleven** elements of the **periodic table** is shown in **Fig. 3.5** (p. 41 of *Modeling*). The Bohr model pictures the atom as a solar system in miniature, with the nucleus analogous to the sun and electrons to the planets revolving around it. Bohr's theorizing led him to introduce various circles or **shells** in which electrons are distributed around the nucleus. Electron orbits of the elements of the first row of the periodic table, hydrogen (H) and helium (He), occupy the **first** shell in his model, that closest to the nucleus. The orbits of the next eight elements of the table, from lithium (Li) to neon (Ne), then occupy the **first** and **second** shells. And after that, the orbits of the next eight elements, from sodium (Na) to argon (Ar), fill the **first**, **second**, and **third** shells.

For understanding chemical reactions, one must focus on the localization of the electrons in the **outermost** shell of each element, for this serves to explain what chemists call the **valence** or **affinity** of that element. Note that we have indicated with an arrow the single valence **electrons** in the outermost shells of hydrogen (H) and sodium (Na) in Fig. 3.5. We have also pointed with arrows to the **missing** electrons in the outermost shells of oxygen and chlorine in Fig.

3.5. The basic principle is that one element combines with another element when both elements are able to **share** or **exchange** electrons so that each **completes** its outermost shell. Applying this principle one can explain why chemical elements **combine** the way they do. One can also visualize chemical **bonding**, with electromagnetic forces serving to unite the atoms, and so explain the **structure** of the resulting molecule.

In his theory, Niels Bohr postulated that electrons move in stable orbits within their shells **without** emitting or absorbing electromagnetic radiation. Under the influence of strong electrical fields or other external energy, however, electrons can make stepwise **jumps** from one shell to another. When they do so they emit or absorb electromagnetic **radiation** in precise amounts determined by the **energy** levels of the shells. Using various rules stating which electron transitions are allowed and which are not, Bohr found that he could explain the emission and absorption **spectra** of the respective chemical elements.

A refinement of this model by another physicist, Arnold **Sommerfeld**, replaced Bohr's circles by **elliptical** orbits. This led to the possibility of the orbits having various orientations in **three**-dimensional space. Thus it provided additional stable **paths** or energy states for the electrons within the atom. Another development was the concept of electron **spin**, that is, the rotation of an electron on its own axis. That gave still more energy states. With each advance, physicists provided a more graphic **picture** of the structural components of each atom. And, in terms of that picture, they could account for most of the element's chemical **properties**.

7. The Inorganic Form

Let us return now to the **epistemic,** non-pictorial model with which we were earlier concerned. Our aim is to explain how these **Bohr-Sommerfeld** models may cast light on the **nature** or inner dimension of an inorganic substance. Of the four causal factors involved in our powers model, we noted that the **formal cause**, the natural form (NF), is the most intelligible. So that is the point at which we start.

The element **sodium** was discovered at the beginning of the nineteenth century. It is the sixth most abundant element on earth, found especially in common **salt** and **sea** water. It is classified by chemists as an alkali **metal**, similar to lithium and potassium. It is very **active** chemically, combining with the oxygen of the air and reacting vigorously with any water with which it comes in contact. When burned in a flame or in a sodium vapor lamp it shines with a strong **yellow** light. And it has many other properties.

A person who has seen this peculiar metal, and particularly one who has experimented with it, can be said to know the **nature** of sodium. But what does one know when one knows that nature? Assuming that the nature has a formal and a material component, as already explained, it is difficult to see how one knows the **matter** directly. At best he can model it as found in the Bohr atom and say that it is formed out of electrons and a nucleus arranged in a special way. This is not too helpful, for the **stuff** of which these particles are made is not known, and the same material components are found in all the other elements in the periodic table.

because

Here the Bohr-Sommerfeld **model** of the sodium atom, which is shown in **Fig. 3.6** (p. 46 of *Modeling*), can be of help. This model differs from that of the simplified electron **shells** of sodium drawn in Fig. 3.5. The circles of the two-dimensional diagram are now replaced with **elliptical** orbits having different orientations in space. Each elliptical orbit contains **two** electrons of opposite spin. And there is still the single **valence** electron in the third shell, which is pointed out with an arrow as it was in Fig. 3.5.

If this model tells us anything, it is that the **organization** or **formal** arrangement of these components, and not the components themselves, makes **sodium** be what it is. This arrangement occurs in nature and is not an artificial form, like the shape of a chair imposed on pieces of wood that maintain their own identity. None of the electrons in the sodium atom acts **simply** as an electron. Rather, each functions as a **part** of sodium. The form that is known and that is modeled in the Bohr-Sommerfeld atom is clearly a **natural** form, a unifying form that confers a new substantial identity on the parts that make up the composite.

To make more explicit this **organizing** function of the natural form, two additional features of this atomic model may be pointed out. One is that a **"free"** electron (one not "bound" within the atom, as are those shown) is completely controlled by its own mass and electric charge. On its own, it would fall **directly** into the nucleus, attracted by the strong positive charge. When within the sodium atom, however, no electron can do that. It must occupy a **unique** energy state in the atom that is occupied by no other. Another is this. When, in a sodium **vapor** lamp, a sodium atom is energized or excited, it **directs** its single valence electron to a higher energy state, funneling into it all of the absorbed energy. The electron again does not act on its own. Instead it is **controlled** by the nature of sodium. It returns to its normal energy state by emitting the **yellow** light produced by a sodium vapor lamp. Again it is sodium as a natural **kind**, the nature of sodium, that **controls** this activity and reactivity. The **natural form** integrates and stabilizes all **eleven** electrons within the sodium atom. It causes them to **function** as an integral and natural **whole**.

8. Chemical Combination

Another view of a natural kind is provided by the element **chlorine** (Cl) and the way it combines with **sodium** (Na) to form sodium chloride (NaCl) or common

salt. Identified as an element only shortly after sodium, chlorine in its natural state is a greenish-yellow **gas** classified along with fluorine (F) as a member of the halogen group. It is **toxic** or poisonous and was the first gas used in chemical warfare. It also has more humane uses. It serves as a germicide and disinfectant, is a good bleaching agent, and is widely used in industry.

Like sodium, chlorine can be **modeled** by the Bohr atom. As already shown in Fig. 3.5, it was pictured with a nucleus surrounded by **seventeen** electrons -- two in the innermost shell, eight in the middle shell, and seven in the outermost. Since it requires only one electron to complete its outermost shell, it **combines** easily with elements that can supply its deficit with one valence electron. That is why chlorine has an **affinity** for sodium and joins with it readily to form common salt.

Those who have seen and smelled chlorine gas know **what** chlorine is. If they have experimented with it extensively they know its many properties. But, as in the case of sodium, they gain a greater insight into its **nature** and its properties when they model it with the Bohr atom. In the chlorine model the electrons and the nucleus are like those in the sodium atom. The distinguishing feature of chlorine is not its **material** composition but rather in the way its components are **arranged**. Again what is at issue is not merely an artificial arrangement. What is present is a **dynamic unity** that makes each component **behave** as a part of chlorine. And we know that unifying factor as the natural **form** of chlorine. This is what enables us to identify chlorine and classify it among the halogen gases.

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Sodium and chlorine unite, as we said, to form a very abundant **compound** easily recognized as **salt**. This is usually seen in purified form as small white particles, or under the microscope as translucent **cubic crystals**. The taste of this substance is distinctive. The facts that it dissolves in water, absorbs moisture from the air, and seasons food are widely known.

Salt obviously has very different properties from both sodium and chlorine, and we may well wonder how it can be formed from those two elements. **Fig. 3.7** shows how chemists explain this in terms of the **Bohr model**, to which we again resort. As indicated in the **upper** part of the figure, single **atoms** of sodium and chlorine combine to form one **molecule** of sodium chloride. The sodium atom transfers its **valence** electron to the chlorine atom and fills its outermost shell. This leaves both atoms electrically charged within the molecule, the first **positively** and the second **negatively**. When a number of salt molecules are present they aggregate under the influence of the resulting electrical **forces** and align themselves in a regular **cubic lattice** (see p. 48 of *Modeling*).

Note again that in this and in the previous cases the **model** of sodium chloride is **not** the nature of salt nor is the model **known** in the same way as the nature.

Far more people know what salt is than know anything about sodium and chlorine. The properties of a **natural kind** such as salt can be grasped quickly on the basis of ordinary experience. But the chemist also knows **what** salt is. In fact, he possesses a **better** knowledge of its nature, for he grasps its **specifying** form in terms of the molecular model shown in the top portion of Fig. 3.7. That gives him a superior insight into its nature, the **inner dimension** that makes it have the properties it does.

The **lower** part of **Fig. 3.7** now lets us put together what we have learned about protomatter and natural form and gain a more **fundamental** view of this interaction. Apart from their nucleus and electron components, both sodium and chlorine are **essentially** composites of a natural form and protomatter. The **nature of sodium** informs and structures the protomatter of that element, and it acts on the **nature of chlorine**, which informs and structures its protomatter. In the course of the reaction the **substrate** is conserved. It carries over all the **potentials** latent within the elements, many of which can be assigned numerical measures. But at the **end** of the reaction the two previous natures **disappear**, to be replaced by a **new** natural form, that of salt or **sodium chloride** (see p. 60 of *Modeling*). This form of salt gives a new **unity** and structure to the compound. It is now no longer modeled by the **atoms** of sodium and chlorine but by the **molecule** of sodium chloride. A new **substantial** unity has been achieved, a new **nature** has been produced, with radically different **properties**. Yet something of the previous substances remains in the protomatter, present as before, still providing the **ontological** ground for the mass-energy that is conserved in the process.

9. Natural Radioactivity

Now let us return again to **Fig. 3.4**, "A Powers Model of an Inorganic Nature." The cases of chemical change we have discussed thus far involve the two forces shown on the **left** side of model, the **electromagnetic** force and the **gravitational** force. Elemental transformations also take place through the two forces shown on the **right** side of the model, the **weak** force and the **strong** force. To illustrate how these forces act, we propose a different example of substantial generation, that, namely, of **natural radioactivity**. The case we shall discuss is the production of the element lead, which occurs in nature, from the radioactive breakdown of uranium, an element that also occurs in nature.

Thus far we have mentioned the atom's **nucleus** and have noted that it is composed of **protons** and **neutrons**. For purposes here we shall use the simplest possible **model** of the nucleus, one that indicates only the **numbers** of protons and neutrons it contains. The nucleus itself will be shown as a circle, and in it **protons** will be indicated by a small circle with a plus (+) inside it, **neutrons** by a small circle without the plus. Since **large** numbers of these particles are present in the nuclei of heavy elements, we shall show only **one** symbol for each type of particle, with a numeral next to it telling how many of each are present.

Fig. 3.8 models the radioactive **breakdown** of uranium into lead (see pp. 60-62 of *Modeling*). This process involves changes in the outer shell of **electron** configurations, as were seen in Fig. 3.7 but are not shown here. It also involves changes within the **nuclei**, along with the controlled **emission** of radiation. We have seen that **quantitative** factors determine the **natures** that are educed from matter through changes involving **gravitational** and **electromagnetic** forces. They do the same through changes involving the **weak** force and the **strong** force as well.

Along the **top** of Fig. 3.8 is written the chemist's formula for what is called the **uranium series**. Uranium does not turn into lead immediately, but does so through a **series** of intermediate elements. The sequence reads as follows: **Uranium** breaks down into **thorium**, which breaks down into **protactinium**, which in turn breaks down into **radium**, which finally breaks down into **lead**. The atomic number and the mass number is given along with each element, so that one can see that **electron** structures and **mass-energy** requirements are changing at each stage. These are accompanied by the **emission** of radioactive products, which are not shown in the formula.

The close **connection** between mass-energy and protomatter, which we have spoken of in previous lectures, should now become clear. Protomatter is the **ontological substrate** that regulates how successive **natures** emerge in substantial changes. And it regulates these changes in such a way as to satisfy the **quantitative** needs of mass-energy conservation. Mass-energy is a measure or a **metric**, but what it measures is really the **potentiality** of protomatter. That is why we have suggested mass-energy as a **surrogate** for protomatter when trying to grasp the concept. It itself, as Aristotelians are well aware, is so purely potential that it borders on the **unintelligible**. lie on the boundary of

10. Summary

Let me summarize what we have done in this lecture. We may do this by reviewing the various figures in which we presented the major points:

Fig. 3.1 diagrammed the six proper powers of human nature, the three cognitive powers, outer senses, inner senses, and intellect, along with the three appetitive powers, will, emotion, and motor powers, which we know from within, as it were. **Fig. 3.2** presented a generic powers model of a nature, showing how matter and form create an "energizing field" in which distinctive powers can be situated. **Fig. 3.3** then showed how Aristotle conceived the powers of inorganic substances in terms of active qualities, passive qualities, and two additional powers, one for rectilinear motion, the other for curvilinear motion. **Fig. 3.4**

replaced Aristotle's powers model for inorganic substances with one suggested by modern physics. **Fig. 3.5** showed iconic models of the first eighteen elements of the periodic table. **Fig. 3.6** illustrated the Bohr-Sommerfeld model of the sodium atom with elliptical orbits. **Fig. 3.7** modeled the generation of sodium chloride from the elements sodium and chlorine. And **Fig. 3.8** modeled the natural radioactivity of uranium.

FIGURES

Fig. 3.1 Human Cognitive and Appetitive Powers

Fig. 3.2 A Powers Model of a Nature

Fig. 3.3 Aristotle's Powers Model of an Inorganic Nature

Fig. 3.4 An Improved Powers Model of an Inorganic Nature

Fig.3.5 Iconic Models of Elements in the Periodic Table

Fig.3.6 The Bohr-Sommerfeld Model of the Sodium Atom

Fig. 3.7 The Generation of a Compund: Sodium Chloride

Fig. 3.8 Natural Radioactivity: From Uranium to Lead

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International Catholic University

Philosophy of Nature

4th Lecture: Nature's Property -- Motion or Change

- 1. Plant Natures
- 2. Animal Natures
- 3. Motion or Change
- 4. Aristotle's First Definition of Motion
- 5. Some Examples of Motion
- 6. A Second Definition of Motion
- 7. Action and Reception
- 8. The Subjects of Action and Reception
- 9. The Distance Traversed

In our last lecture we developed an **epistemic model** to assist our understanding of **natural kinds** and how these kinds give rise to characteristic activities from within themselves. **Nature**, as we have seen, is the basic principle of operation within natural substances, and it exhibits itself in two ways. First, it presents itself as an active and actualizing principle within the substance, which we recognize as a **form** and which we call its substantial or **natural form**. Second, it presents itself as a potential and conservation principle, which we recognize as **matter**, a basic material stuff within the substance which we call prime matter or **protomatter**.

In developing our model we proposed to model **natural form** as an energizing field, taking inspiration from modern robots, which can simulate nature's functions when they are properly energized. The natural form energizes kích hoat **protomatter**, which in itself lacks all distinctive attributes, and so we represent it as a circular **field** expanding out from a central **point**. The point represents protomatter, which may be thought of as the **opposite** of a **black hole** from which the natural form emerges. And within this energizing field we situated the **powers** that are proper to, and indicative of, a particular natural kind.

In modeling an inorganic nature -- as studied, for example, in physics and chemistry -- we simply appropriated the four basic **forces** found in the physical universe. These are the powers we now use to explain the activities and reactivities of **non-living** substances. We arranged them symmetrically within the field, since they are actually powers of the nature as natural form. They are usually enumerated, with their symbols, as the electromagnetic force (**EF**), the gravitational force (**GF**), the weak force (**WF**), and the strong force (**SF**).

At the end of the last lecture we promised to augment this model of inorganic nature so that it could also be applied to two additional genera of natural kinds, those of **plants** and **animals**. Just as we used four powers to explain the properties of inorganic natures, we shall find that **four** additional powers each suffice to characterize plant natures and animal natures.

1. Plant Natures

Plant natures -- as studied, for example, in botany -- are obviously more **complex** than inorganic natures. Apart from their atomic and molecular parts they are **organisms** with their own systems and functions to account for. Aristotle was aware that plant organs exercise **three** basic powers that are required for life processes. These he enumerated as **nutrition**, **growth**, and **reproduction**. Modern biologists would add to these **homeostasis**, the power whereby an organism maintains its stability while adjusting to the **environment** in ways that are best for its survival. With this addition we have the **four** powers required for plant life. Adapting to modern usage, we shall change their names slightly from those used by Aristotle.

I am using graphical aids throughout these lectures that are available to those taking the course for credit. Some of the figures are found in my *The Modeling of Nature*, published by The Catholic University of America Press in 1996. We enumerate these four powers, with their symbols, as shown in **Fig. 4.1** (p. 95 in *Modeling of Nature*): the homeostasis control (**HC**), the metabolism control (**MC**), the developmental power (**DP**), and the reproductive power (**RP**). These, then, are the four basic **vegetative** powers. They must be added to the four inorganic powers we have already enumerated to provide a total of **eight** powers to account for all the activities of a plant form.

Figure 4.1 diagrams the powers model of a **plant nature**. Like that for an inorganic nature, it starts with a **point** source, labeled **PM** for **protomatter**, as heretofore. This is surrounded by an energizing **field** that radiates from it and constitutes the plant organism -- now labeled **NF$_p$**, for **natural form**, with the subscript "p" designating **plant**. Within that field, as before, the **eight** powers are arranged symmetrically, but also hierarchically, with the inorganic powers in the **lower** hemisphere, the organic powers in the **upper**.

Notice the **up** and **down** arrows on either side of the letters PM, connecting the two sets of powers and showing the **interchanges** between them. These have a slightly different function from the arrows we have used previously in the inorganic model. Our earlier use of arrows represented **activities** that originate or terminate **outside** the substance being modeled and on this account are called **transient actions**. As opposed to them, the up and down arrows on either side of the PM designate **immanent actions**, those that remain within the plant and are perfective of it. Plants also initiate a few transient activities, as can be seen from the single arrow emerging from the **reproductive** power, when it produces seeds and brings into being a new organism of its own species. Also the two reciprocating arrows attached to the box for **homeostasis** show that it **controls** environmental reactions with substances that exist **outside** the plant.

The function of the **plant** form $\mathbf{NF_p}$ with respect to the **inorganic powers** in the lower part of the model is obviously different from that of the inorganic form $\mathbf{NF_i}$ in the non-living. The atomic and molecular structures these powers control are now **part** of the plant, and they are regulated by the form (mainly through its **metabolism** power, **MC**) to meet the energy requirements of the plant's life. The **natural form** $\mathbf{NF_p}$ further determines the way in which this nutritive energy is used, through its developmental power **DP**, controling the distinctive patterns in which the plant grows and stops growing. And finally, the natural form channels energies of the adult form, over and above those required to sustain its own life, through its reproductive power (**RP**), for the **generation** of **new organisms**.

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As in the case of inorganic natures, the **generic** power form is not sufficient of itself to model a **specific** plant nature. To this has to be added **iconic models** that portray in detail plant structure and functioning. These are different, for example, in algae, fungi, mosses, and vascular plants. Each of these **phyla** has its characteristic root, stem, and leaf systems, and uses them in various ways for **transpiration** and **reproduction**. These have been understood and sketched by **botanists** for centuries, but with the development of **biochemistry** in recent decades, much more is known about metabolism and replication. **Graphic** modeling techniques make these life processes interesting and intelligible even to those who have little formal education in the sciences that specialize in them.

2. Animal Natures

From this you get the basic idea of a generic **powers model** and the way it can be used with **iconic models** to gain an insight into natural forms of the organic and inorganic types. As we move up the scale into the **animal** kingdom the powers of the natural form become more **complex**. Animals differ from plants basically in two respects: they possess **knowledge** of objects external to them, and they are able to **move** locally, typically from place to place. For these they require **four** new series of powers. We shall enumerate them, with their symbols, as shown in **Fig. 4.2** (p. 105 of *Modeling of Nature*): the outer senses (**OS**), the inner senses (**IS**), the motor powers (**MP**), and the emotional reactions (**ER**). These should be familiar to you, for we have already discussed some of them in previous lectures.

Figure 4.2 builds on the materials provided in Fig. 4.1 to diagram these powers of an **animal nature** -- the type studied by zoologists. Now we have, in addition to the four **inorganic** powers and the four **vegetative** powers, the four basic powers of **sensitive** organisms, for a total of **twelve**. These are again arranged **hierarchically**, with the inorganic powers at the **bottom**, the vegetative powers in the **middle**, and the sensitive powers at the **top**.

Animal organisms are receptors and initiators of **transient actions**. This can be seen in the top set of boxes -- with the inwardly directed arrow on the outer senses (**OS**) box and the outwardly directed arrow on the motor powers (**MP**) box. They also manifest more **immanent action** than plants. This should be obvious in the arrows connecting all four of the sensitive powers **internally**, showing how each influences and is influenced by the others. Immanent action is also seen in the **two** pairs of **up** and **down** arrows below and above the middle set of powers. As in the case of the plant form, the **pairs** of arrows are meant to show the **relationships** among all **twelve** powers of the three sets. The lower pair indicates how the four powers of the inorganic **subserve** the four plant powers. The upper pair show how the plant powers in turn **subserve** the needs of animal life. Viewed in another way, the four sensitive powers of the animal kingdom **require** all eight powers of the vegetative and mineral kingdoms for their proper operation. The **ensemble** of these powers operating within the animal is what constitutes its **nature** or specifying form. This, as previously, is modeled by the radiating circles or **field** labeled **NF**$_a$, with the subscript "a" meaning **animal**. This natural form **energizes** all the powers and enables them to function as a specific organic unit. As before, it is the ontological **correlate** of protomatter (PM), shown at the center of the figure.

To understand Fig. 4.2 fully it must be associated with an organism of a **particular** species, say, a squirrel. A live, adult squirrel is able to exercise all of these natural powers, and it does so in ways that contribute to the **unity** and well-being of the entire organism. Its life has an inorganic **base** in the sense that its bodily components obey all the laws of physics and chemistry. It also is able to provide its own **vegetative** functions -- it assimilates its food and grows and develops, and eventually procreates its own kind. All of these functions then undergird its **sensitive** and **mobile** capacities.

There are, of course, many more **species** of animals than there are of plants.

The two major divisions are the **invertebrates** and the **vertebrates**, the second including all the fishes, amphibians, reptiles, birds, and mammals we commonly call animals. All of these have distinctive **organ systems** for carrying out the activities they share with plants as well as those that are properly their own. And many of these functions can be modeled and understood in terms of **iconic** models, as in the case of robots used to emulate animal activities.

It is important, however, to remark on an important respect in which a **natural** squirrel differs from a **robot**. The natural squirrel is self-developing and self-activating -- another way of saying that it is **alive**. Robots work only when they are **externally** powered or energized. The squirrel is energized **by nature**. And yet the concept of being energized casts light on the **function** of the natural form in the realm of the living. Just as a robot is inert or **dead** when it lacks a source of energy, so the squirrel is dead when it is no longer **animated**. Then it no longer has its **nature**. Then the **powers** deriving from that nature are **inoperative**. Its structure **disintegrates** and the organism itself decomposes into **inert** chemical substances.

3. Motion or Change

With this we are in a position to examine the major **property** of natural beings, the property that differentiates them from mathematical beings and incorporeal beings, that is, their ability to undergo **change**. Another way of saying this is that the **subject** of natural philosophy is **moveable** or changeable being. In Aristotle's vocabulary the same term was frequently used for **motion** and **change**. So when he defined nature as a "principle of motion and rest," he used the word "motion" to refer to all changes that take place from within a natural body. And he himself points out, at the beginning of the third book of the *Physics*, that "if we are ignorant of what **motion** is, we are of necessity ignorant of what **nature** is." Hence the importance of being clear on what we mean by the term motion.

change?

From the materials we have just covered on inorganic, plant, and animal natures, it should be obvious that natural kinds undergo many types of changes or motions. The most obvious motions are the change of **place** of a falling body, the change of **size** of a growing plant, the changes of **color** in a plant's leaves or fruit, and the various **movements** of animals, from the flight of the bird to the leap of the jaguar. There are also the **substantial** changes we have been illustrating in physics and chemistry -- the generation of **salt** from sodium and chlorine, the decomposition of **water** into oxygen and hydrogen, and the radioactive breakdown of **uranium** to lead.

To put some order into our discussion, let us note that the English word "motion" can be taken either in a **strict** sense or in a **wide** sense. In a **strict** sense it has the same meaning as the Greek *kinesis* and the Latin *motus*, from which the English **motion** obviously derives. In a **wide** sense it can be extended to include also the meaning of the Greek *metabole* and the Latin *mutatio*, which may be translated as **mutation** or **change**. In what follows we shall focus on the first or stricter meaning -- we shall take motion to mean a **movement** that can be perceived by the **senses**, that is **successive** and continuous, and that takes place in **time**. This definition would apply to the fall of a heavy body, the growth of a plant, the change in color of its leaves, and the various movements of a squirrel's body.

Notice that there is one type of change we have already considered that is **not included** in this stricter meaning. I refer to change of substance -- **substantial change**, that from one natural kind to another. This type of change is recognized by the **intellect**, but it is not directly perceived by the senses. Or, to put it another way, it is seen by us as **instantaneous**. First we have water, then we have oxygen and hydrogen. Water ceases to be, there is a transition from **being** to **non-being**; oxygen and hydrogen come to be, there is a transition from **non-being** to **being**. There is nothing **intermediate** beween being and non-being. We have tried to indicate this in modeling changes of this type by a pair or a series of **parallelograms**. In the case of the pair of parallelograms, there is a **flip** from one to the other, with **protomatter** anchoring the base and different natural forms **immediately** activating it. In the case of the uranium series of parallelograms, protomatter was the subject that was **conserved** throughout the radioactive breakdown, with different natural forms appearing successively. Protomatter was **never** without a natural form, **always** with some form or other, **never** in an intermediate state between being and non-being. A **natural kind** was always identifiable, and could be seen as uranium, thorium, protactinium, radium, or lead at each stage throughout the process.

4. Aristotle's First Definition of Motion

Now we focus on **motion** in the first or strict sense as sensible and successive movement and consider how it may be **defined**. One of the easiest ways of defining an entity, for Aristotle, is to locate it in one or other category of being. We have enumerated his **ten categories** of being, and now find that it is no simple matter to situate motion in a particular category, since it is found in more than one category. **Change** is situated in the category of **substance**, but we have eliminated that because it is not sensible and successive motion. Yet change or **movement** in the sense we are now taking it is also found in the category of **quantity**, as in the growth of a plant or animal from small to large, in the category of **quality**, as in the change of color or temperature, and in the category of **location**, as in movement from here to there. What terms can be used to define a type of being that **spans** these three categories?

Aristotle's philosophy is distinctive in its treatment of this problem. Another Greek philosopher named Parmenides had denied that there could be any intermediate between **being** and **non-being**. Aristotle contested this view with a teaching we have already seen, namely, his teaching on **act** and **potency**. Between **nothing** and something in **act**, Aristotle maintained that there is a third possibility, namely, something in **potency.** We have used this concept in previous lectures when discussing **protomatter** as a type of potential being. We have used it also when discussing **powers** as abilities or potencies that are sources of activity in natural kinds. Aristotle's solution of the problem of motion was to situate motion **midway** between actuality and potentiality.

When a body is only in **potency** to a particular state, Aristotle reasoned, it is **not yet** in motion. When its potency to that state has been fully **actualized**, the motion has ceased. Therefore, motion consists of something in between potency and act. It is an **incomplete act**. But one has to be careful with the expression "incomplete act," because it may be difficult to see how an **act** can be **incomplete**. To remove the difficulty Aristotle thought it necessary to add, beyond the indication that motion is the **incomplete** act of being in potency, that the thing moved had to be **still in potency** to **more and more** of the same act. This line of reasoning led him to the classical definition: "**Motion is the actualizing of what exists in potency insofar as it is in potency**." The definition is difficult to understand, but let us break it down into three components: **(1)** motion is the actualizing **(2)** of what exists in potency **(3)** precisely as it is still in potency.

Fig. 4.3 is a diagram that will assist us in **unpacking** these components. In it we analyze the motion of **heating** as seen in the heating of water from 0° to 100° C. Note that there are two beakers in the figure, one **standing** alone on a table, the other on a Bunsen burner with a **flame** under it. Let us assume that, at the moment illustrated, there is a **thermometer** in each beaker and that both read **30°** . In the case of the water standing in the beaker at 30° and, say, in an ambient medium that is also at 30°, the first **two** elements of the definition have been verified. When at 0° the water was **in potency** to being at 30°, and that potency has now been actualized, so we can say that the water heated to 30° is an example of **(1)** the actualizing **(2)** of what exists in potency.

Now contrast this with the case of the water **being heated** on the Bunsen burner. At the moment shown, the water temperature as measured by the thermometer reads 30°, indicating not that the water is standing at 30° but rather that it is "**transiently**" at that temperature, that it is "**passing through**" 30°. Obviously in this case the first **two** elements of the definition of motion are verified, for this also is **(1)** the actualizing **(2)** of what exists in potency. But here something more is going on. In the case of water actually heating, the water not only has been heated to 30°, but in the very attainment of the 30th degree it is already **on its way** to a higher degree, that is, to **further** actualization. That is the sense of the third element, **(3)** precisely as it is still in potency to further actualizing. In the second case the actualizing at 30° is an **imperfect** actualizing, and the **on-going** actualizing of its continuing potency (which is its **"passing through"** that degree) is what is meant by motion. In this case, that is what is meant by the water **heating**.

Perhaps, in thinking about this, you wonder why we do not put into the definition of heating such expressions as that the water is **"transiently"** at 30°, or is **"passing through"** 30°? The reason is simple. To do so would in effect be using a **synonym** for motion to define motion. Being "transiently at 30°" or "in transit through 30°" or "passing through 30" is just another **way** of saying that the water is heating, and so the definition would be circular. Aristotle would overcome this difficulty by focusing on the "in potency" in the definition and using it **twice** (or **reduplicatively**). "Motion is the actualizing of what exists in potency precisely as it is in potency." This uses only act and potency and still can capture the essence of motion. Aristotle admitted that this definition is **difficult** to grasp, but it is not circular and, he went on to say, it is **not** incapable of existing.

5. Some Examples of Motion

The example of heating is a change of **quality**, a motion that is referred to as **alteration**. The other two types of motion to be considered are change of **location**, which is referred to as **local motion**, and change of **quantity**, which is referred to as **augmentation** if the quantity **increases** and **diminution** if the quantity **decreases**.

Let us repeat our analysis for the case of **local motion**, which is the easiest to understand and provides the paradigm for the other two types of motion. Suppose that a bird is flying through the air from a tree to a church steeple. When is the bird flying? It is flying when it has **left** the tree and has **not yet** arrived at the church. Flying then is covering a distance when **part** of the distance has been traversed and **more** of the distance remains to be traversed. In this sense it is the actualizing of the potency to be in a **different** place, while still in potency to a yet **more distant** place. Suppose that in flying to the church from the tree the bird **alights** on a telephone pole. As soon as it alights on the pole it has **stopped** flying and that motion has been completed. Then the case is similar to that of the water **standing** at 30°. If the bird **takes off** again and continues on to the church steeple, it is flying **again**, but now with **another** motion.

Earlier we mentioned that plants and animals both have a developmental power which is the cause of **growth** within the organism. This is not growth by **accretion**, the pasting on of new parts from **outside** the plant or animal. It is growth from **within**, by a process of metabolism and **nutrition**, as we have tried to explain. When, then, is an organism **growing**, or undergoing augmentation? When it has **already** grown but has still **more** to grow. The case is exactly the same as the water heating and the bird flying. The plant or animal is growing when it **has** grown and **will be** growing -- precisely at the point **in between** what has already occurred and what has yet to occur.

6. A Second Definition of Motion

Now let us return to the case of the water heating over the Bunsen burner, for here it is a simple matter to identify the **agent** that is causing the heating, namely, the flame under the water. We already have a general idea of what causes the bird to fly and the plant to grow, namely, the **motive power** within the bird and the **developmental power** within the plant. With the bird and the plant we are dealing with **immanent actions** in the sense that its motion and its cause are in the **same** substance. But in the case of the water heating, we are dealing with a **transient action** and with **different** substances, the fire and the water, and this presents an interesting problem. It enables us to learn something more about motion, and also to get a better insight into efficient causality.

The question here basically concerns the **subject** of motion. We know what motion is, and we may wonder **where** the motion is. To put the question more precisely, is the heating in the **water**, or in the **flame**, or is it in **both**? The answer to that question leads us to the first **a priori** demonstration in the science of nature. It will be *a priori* because it will follow from the definition of motion we have already established, and it will actually provide us with a **second** definition of motion. The demonstration will show that the heating is **properly** in the water, that is, that the proper subject of motion is the **thing moved**, the **moveable**, in this case, the **thing heated** or the heatable, the **water** being heated.

Fig. 4.4 presents the demonstration in syllogistic form, which reads as follows:

> The actualizing of what is in potency
> insofar as it is in potency
> **is** the actualizing of the moveable (changeable)
> insofar as it is moveable (changeable).
>
> But motion **is** the actualizing
> of what is in potency
> insofar as it is in potency.
>
> Therefore, motion **is**
> the actualizing of the moveable (changeable)
> insofar as it is moveable (changeable).

The first sentence here, called the **major premise**, merely restates the result of the reasoning process we have just gone through. What we are talking about is an **actualizing** of a potency that is going on. What **potency** are we focusing on? It is the potency **of a subject** that is capable of being moved or changed. The subject here is the water being heated. That is precisely what we have been talking about.

Now look at the second sentence, called the **minor premise**. This is the **first definition** of motion, which we have already established.

When we put the two together, we get the **conclusion** immediately: **Motion is the actualizing of the moveable (changeable) insofar as it is moveable (changeable)**. Reflecting on this we can see that we have here **another** definition of motion, which is referred to as its **second** definition. The first definition, expressed in the minor premise, describes motion in terms of its proper **formality**, or in terms of its **formal cause**. The new definition describes motion in terms of its proper subject, its proper matter, and so in terms of its **material cause**.

The middle term of the syllogism here is a formal **cause**, and it concludes to a formal **effect**, namely, the proper subject in which motion is found. Hence the demonstration, going from cause to effect, is **a priori**, as we explained in our first lecture.

Let us now illustrate the second definition of motion in terms of the **examples** we have already given of the first definition.

In the case of **heating**, which is an **alteration**, "motion is the actualizing of the potential insofar as it is potential" now translates into "heating is the actualizing of the **heatable** insofar as it is heatable." The heatable here is the **water** being heated by the flame. Where is the heating? It is **in the water**.

In the case of flying, which is a **local motion**, "motion is the actualizing of the potential insofar as it is potential" translates into "flying is the actualizing of the bird's **ability** to be in a **place other than** where it now is." In other words, flying is **in the bird**, the subject that is successively in the **different places** that are traversed.

In the case of **growing**, which is an **augmentation**, "motion is the actualizing of the potential insofar as it is potential" translates into "growing is actualizing of the plant's ability to be of a **size larger than** it now is." In other words, growth is **in the plant**, the subject that is successively undergoing increases in its **dimensive quantity**.

7. Action and Reception

Admittedly it is easier to see that flying is in the bird and that growing is in the plant than it is to see that heating is in the water. The reason for this is that the flying and the growing are activities of living things and thus they involve elements of **immanent activity**, that is, activity that in some way remains **within** the agent that is causing it. The heating of the water is different in the sense that the heating passes **out of** the flame and **into** the water. In other words, it is an instance of **transient action**. In such an action it seems that there is a sense in which **heating** can be attributed to the flame. After all, it is the flame that **heats** the water, so why is not heating also in some way in the flame?

It was consideration of difficulties such as this that led Aristotle to augment the number of **categories** beyond those we have already been treating. Thus far, of the ten categories, we have looked at four: the categories of substance, quantity, quality, and location in place. Now there are **two more** among those we enumerated earlier that attract our attention. These are the categories of **action** and **reception**. We need these precisely to address the problem we have now raised.

Fig. 4.5, in its **upper** portion, shows a simple schematic diagram of the flame heating the water. The flame is shown as a **circle** and the water as a **box**. The two are touching, to indicate that the flame is **in contact** with the water. There is an arrow in the box that starts at the point of contact and otherwise **traverses** the box. This arrow represents **motion**, in this case the heating. Notice that it is **in the water**, because it is the water that is being heated. But the heating involves two things, the flame and the water. The flame is the **agent** or the physical cause of the heating, and its operation is called **action**. The water is the **recipient** of the agent's action, and its receiving is called **reception**. In Latin "reception" is termed **passio**, and this terminology passes over into English, so that reception is frequently called **passion**. Thus we have the couplet "action and passion," which means the same thing as "action and reception."

From the diagram it appears obvious that the **action** and the **reception** are both intimately related to the motion. In fact, they are **really** the same thing as the motion. Action is motion as it is **from the agent**, and reception is motion as it is **in the recipient**. Consider now, in the **lower** portion of Fig. 4.5, the arrow we are using to represent the motion. The left part of the arrow, that beginning with the point of contact where the circle and the box intersect and extending forward, can be seen as representing the **action**. The right part of the arrow, that starting with the arrowhead and extending backward, can be seen as representing the **reception**. Both are identified with the motion, but as seen from different directions.

Consider now the question: are the left part of the line and the right part of the line really different from the line itself? Clearly, there is a **real distinction** between the left part of the line and the right part of the line. The one is **not** the other. And, in a sense, the two parts of the line are also different from **the line** in its entirety. But they are different in a minimal sense that depends on the **mind's** way of considering things. This type of difference is known as a **distinction of reason**. Action and reception are **really different** from each other, but they are different from motion merely by a **distinction of reason**.

8. The Subjects of Action and Reception

Now a further question arises. We have seen that **motion** is in the moveable, that is, it is in the **recipient** of the action. But **where** is action and **where** is reception? With regard to the second, **reception**, there is no problem. Obviously it is in the **same place** as the motion, and so it is in the **recipient**.

With regard to the **action**, however, the answer is not as simple. Is there an **actualizing** in the agent that corresponds to the agent's **activity**? Surely **there is** in the case of the flame, if the flame is heating the water. But now take the Bunsen burner out from under the beaker of water and put it to one side with the flame still burning. Is the flame now burning **by itself** still an agent, if it is not heating the water? One can make a distinction here. There is a sense in which the flame can be regarded as a **heating agent** even when it is not heating. This is in the sense that the flame is **able to heat**, or has the **power** to heat, even though it is not heating. We can refer to this as the flame being an agent **in first act**, that is, as having the **potential** to heat. But it is only when the flame is in contact with the water, and heating the water, that we can say it is truly an **efficient cause**. We say then that it is an agent **in second act**, that is, that it is a cause **actually causing**. For it is only then that the flame is **really** heating the water and so is the efficient cause of the water's being heated.

All of this discussion, it turns out, is relevant to answering the question, "**where** is action?" It seems to be **in the agent** when the agent is in second act. But the action will already have had to be transferred to the recipient if the **causing** is actually taking place. Therefore there is a strong case for the action being also **in the recipient** when the agent is in second act. This twofold solution is usually accounted for by saying that predicamental or **transitive action** exists in **two** places. It exists **inchoatively** or in incipient fashion in the **agent**, but it exists **terminatively** or in completed fashion only when it is in the **recipient**. It is only **then** that the flame is a cause actually causing the water's being heated.

Action and reception do **not** constitute separate types of motion, for they are really **identified** with motion. As we have said, **action** is motion considered as being **from** the agent, whereas **reception** is the **same** motion considered as **in** the recipient. It is noteworthy that **none** of the remaining **categories** of being -- relation, time, situation, and vestition -- give rise to **additional** types of motion. It is true that **changes** occur in these categories, but none do so **directly**. They always occur through a prior change in one of the **three** types of motion we have already discussed, namely, those in the categories of **location, quality**, and **quantity**. It is changes in these that indirectly give rise to changes in the category of **relation, time, situation**, and so on.

9. The Distance Traversed

From what we have said thus far, it should be clear that motion or change, in the sense we have been considering it, is **sensible** and **successive** movement. That is, it is **perceptible** by the senses, and it does not take place instantaneously but does so over a **period of time**. Another way of stating this is to say that sensible motion always **traverses** a **"distance"** of some sort. This is most clearly seen in the examples we have already analyzed of the bird's **flying** and the plant's **growing**. When the bird flies from "here" to "there" it obviously traverses the **distance** between the two **places**, for example, that between the tree top and the church steeple. And when the plant **grows** from "small" to "large" there is a change in its **quantitative dimensions**. The plant always has some **size**, but the size changes as it grows. The interval between **small** and **large**, in its case, is similar to the interval between **here** and **there**, and in this sense we can say that the plant also traverses a "**distance**" as it continues to grow.

The heating of the water is slightly different. In the other two cases it is easy to see that the distance can be **quantified**. There is a distance of **length** in the flight of the bird, and there is a distance of quantitative **dimensions** in the growth of the plant. The heating of water can be quantified **also**, but this has to be done through a process of **measurement**. The water's heating can be measured through the use of a **thermometer**, which measures the **degree of heat** within the water at any one moment. This gives a quantitative **measure** of heating, since through the process of measurement the heating comes to be seen as the **traversal** of various degrees of heat from 0º to 100º. Earlier in this lecture we have used this "distance," and its traversal, to explain the first **definition** of motion given by Aristotle. Analogous measures of other changes in quality are also available. Through their use all **alterations** of sensible qualities can also be seen as traversing a quantitative length -- what we have been calling a "distance."

We may refer to the three types of motion -- local motion, growth, and alteration -- as motion's **qualitative parts.** Apart from these "parts," motion has also **quantitative parts** by reason of this distance that it traverses. These quantitative parts are best seen in local motion, where the magnitude the motion traverses, otherwise known as **extension**, manifests all the properties of a **continuum**. Since in the other types of motion the change is in some way sensible, we may say that all motion traverses the **sensible continuum**. Thus motion is, by its very nature, **continuous**.

But the continuum that is **motion** is not the same as a **static** continuum such as a **line**, all of whose parts co-exist and are known at the same time. Rather motion is a **flowing** continuum. Like the line, it has parts, but these parts come **into existence** only successively. We know the parts of a motion only because we are able to retain them in **memory**. We shall explain this peculiar aspect of motion in greater detail in our next lecture, after we have treated the subject of **time**.

FIGURES

Fig. 4.1 A Powers Model of a Plant Nature

Fig. 4.2 A Powers Model of an Animal Nature

Fig. 4.3 The Heating of Water

Fig. 4.4 The Proper Subject of Motion

Fig. 4.5 Motion, Action, and Reception

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International Catholic University

Philosophy of Nature

5th Lecture: Nature's Measures -- Place and Time

- 1. The Concept of Place
- 2. Aristotle's Definition of Place
- 3. Place in the Universe, Old and New
- 4. The Concept of Space
- 5. Voids and Vacuums
- 6. The Concept of Time
- 7. The Continuum
- 8. The Existence of Time and Motion

Thus far in our course on the philosophy of nature we have treated **matter** and **form** as the **intrinsic principles** of nature's operations. In our last lecture we examined **motion** or change as the pervasive **property** of the world of nature. This has taken us through the first **three** books of Aristotle's *Physics*. In this lecture we move on to the **fourth** book of the *Physics*, where Aristotle takes up what he refers to as nature's **measures**: **place** as the measure of the moveable **body**, and **time** as the measure of the **motions** moveable bodies undergo. We shall also take up some additional topics, from the **fourth** through the **sixth** book, relating to **space** and the **void**, and to the properties of the **continuum** as related to both time and motion.

1. The Concept of Place

The Latin word for place is *locus*, and it is the root from which we derive the word "local" as used in the expression **local motion**. From our previous lecture we know that local motion is very important, for it provides the paradigm in terms of which we understand other types of successive motion or change. Thus if we do not know what place is, we will have difficulty grasping **change of place**, the most common **motion** in the universe. Again, the category of

location, the answer to the question "where?" (in Latin, *ubi*), would be very difficult to determine if we had no grasp of the meaning of place.

The most important thing to note about place is that it is a **physical** or **natural** concept, **not** a **mathematical** concept. The mathematical concept that is most closely related to place is the concept of **space**, which we shall also be discussing. Whereas the natural philosopher studies **place** and **time** as **natural** measures in the universe, the physicist studies **space** and **time** as the **mathematical** measures most used in his discipline. The two concepts, place and space, should not be confused, for they refer to quite different entities.

When I say that place is a physical or natural concept I mean that it is closely tied to the **nature** of a thing. Every natural body has a place or **environment** to which it is properly suited -- what we refer to as its **natural place**. As we have seen, natural bodies have **powers** that initiate and sustain their activities, and these powers are in many cases directed **outside** the body to other bodies in their surroundings. An important instance of this is **gravitational force**, which is found in all natural bodies, both living and non-living. Another significant instance, and this for living things, is **homeostatic control**. This power is essential to survival, for it regulates the responses of plants and animals to the entities and circumstances making up their **ecology**.

In **defining** place we should bear in mind the following three points. First, for **local motion** to be possible there must be places in the world in which bodies can **succeed** one another. Second, places must be **real** and must be something **distinct** from the body or bodies that are in them. If the place of a body were **not** distinct from the body, a moving body would take its place **along** with it and would have the same place **after** the motion as **before**. And third, for local motion to occur the place **previously** occupied by a body must remain **unchanged** when the body leaves it, and that the **new** place must also be **unchanged** as the body moves into it.

A good model for place is some type of **vessel** or container. Place is like a container that can be **emptied** of one thing and **filled** with another, and remains distinct from the things it successively contains. One may ask, for example, "**Where** is the honey?" and get the reply, "It is **in** the jar." The jar is, in a sense, the place of the honey. But the jar is an artifact, and now we are concerned with finding a containing place **in nature** that will fill the same function as the jar in the cupboard. Perhaps before being in the jar the honey was in a honeycomb, and how would we go about defining that kind of place?

Well, for one, place should state the **environment** in which a natural body exists. Again, place should be seen as **surrounding** the object in place. Yet again, this surrounding environment should be **distinct** from the located body. And finally, the **exact** place of a thing should be **physically equal** to the thing located in that place. For example, in a jar filled with honey the place that surrounds the honey is **neither** larger **nor** smaller than the volume of the honey itself. The **volume** of a place should be equal to the volume of the **body** in place.

2. Aristotle's Definition of Place

To meet these requirements Aristotle proposed a **definition** of place that has been much debated through the centuries. He proposed his definition, of course, in the context of a spherical geocentric universe of finite size that is very different from the universe we conceive in the present day. We shall first explain the definition he offered in its original context, and then see how it may be adapted to the modern context.

The definition is succinct. In English it reads as follows: **Place is the primary motionless boundary of that which contains**. In his commentary on this definition St. Thomas divides it into two parts. He identifies the expression "boundary of that which contains" as the **genus** of the definition and the expression "primary motionless" as its **difference**. Let us examine each in detail.

Place is "the boundary of that which contains." This is the genus. Another term for **boundary** is **surface**, so place is in some way similar to the outermost surface of the body that is in place. Actually it encloses this outermost surface of the body in place, for place is the surface immediately **outside** that surface. This will be the **innermost surface** "of that which contains," namely, the innermost surface of the medium that immediately surrounds the body. Thus place will be the first surface **outside** the body in place.

I should note that I am using graphical aids throughout these lectures, and they are available to those taking the course for credit. If you have these, consider the first diagram in the upper portion of Fig. 5.1. It shows a rubber **balloon** filled with helium that is floating in air, attached to the **ground** with a string. Here the boundary of that which contains, or the container, is the **surface** of the air that immediately **surrounds** the balloon. This surface is directly in contact with the **outside** of the rubber of which the balloon is made. That suffices to answer the question, "**Where** is the balloon?" It is **in** the air. The second diagram there is similar. It shows a **table** in a **room**. Supposing that the **only** surface we know that **surrounds** the table is that defined by the **walls** of the rooms, we can answer the question "**Where** is the table?" The table is **in** the room. That is its place, taking place in a **general** way.

This brings us to the **difference** of Aristotle's definition, expressed in the words "**primary motionless**." There are two further **precisions** we can now make about our first determination. One relates to specifying more **precisely** where the table is located within the room. The other relates to the surface of the air in **contact** with the balloon when that surface may be **continually changing**. If the air is **blowing**, for example, and **different** air keeps touching the balloon's surface, does that make the place of the balloon **change** also? The words "primary" and "motionless" are added to take care of **problems** such as these.

Assume now that there is air in the room and the air is **circulating**. In such a case, as is shown in the lower portion of Fig. 5.1, there is always a **layer** of air touching the table on all sides. Then the "primary motionless" surface refers to the air that is touching and **circulating** around the table's surface. It refers, however, **not** to the particular air that is moving, but rather to this layer of **air** as it is **related** to the walls of the room that are at **rest**. The walls are **motionless**, and they are the primary **referent** for fixing the table's place. A specific place always involves a **relationship** to something **stationary**. This is indicated by the layer of air outlined around the table, with arrows drawn from it to the walls of the room. This particular relationship further **specifies** the table's location within the room.

The same reply applies to the **balloon** in the air when the air is **blowing**, also shown in the lower portion of Fig. 5.1. It is not the particular air contacting the balloon that determines its place, but rather the changing **layer** of air that is continually being **related** to the ground below the balloon. The ground is at rest and it remains as the **stationary** surface of reference. It provides what Aristotle would call the "primary motionless boundary" of the air that determines the balloon's proper place.

3. Place in the Universe, Old and New

earth, water, air, fire

The **universe** of Aristotle and Thomas Aquinas was more **orderly** and more **static** than the universe of the twenty-first century. With regard to the **elements**, **gravity** was the basic force that dictated the **natural order** of the **sublunary** region. The ideal order was that of concentric orbs arranged around a **center** of gravity, which was also the center of the **earth**, as shown in **Fig. 5.2**. The innermost sphere was that of the Earth itself, **earth** being the heaviest element. Next to it was the sphere of the next heaviest element, **water**. After that came the sphere of **air**, which was lighter, and finally the sphere of **fire**, the lightest of all, extending to the sphere of the moon.

These spheres also determined the **natural places** of the bodies whose natures we have been considering in previous lectures. The natural places of **plants** and land **animals** were on and in the surface of the earth, those of **fishes** were in the waters, those of **birds** in the air, and those of **meteors** and **shooting stars** in the sphere of fire.

In the heavenly regions, beginning with the sphere of the **moon**, came respectively the orbs of the **planets** Mercury and Venus, then the orb of the **sun**, and after it, in succession, the orbs of Mars, Jupiter, and Saturn. The outermost sphere, finally, was the sphere of the fixed **stars**. This sphere, with its majestic and **uniform** daily rotation, served as the timepiece for humans. It also provided the **ultimate** frame of reference for locating **every** creature or **nature** within the universe, from the inorganic to the organic, from earthly bodies to those in the farthermost reaches of the heavens.

Our universe of the twenty-first century is much more **dynamic** and changing than this pre-Copernican universe. Yet we have no difficulty **locating** within it every object known to human beings. Surprisingly, Aristotle's **gravity** is still an important determinant of place, particularly for the regions within which we humans live. What **is** new is the notion of the "Big Bang" and the **expanding** universe it seems to have produced. This has introduced a **new** reference point, a new "primary motionless" that is different from a center of gravity, and is almost its opposite. The Big Bang introduces a kind of **levity** within the universe, one that causes objects to **flee** from the center rather than be drawn to it.

But from this point of "galactic recession," as it has been called, we can now **locate** star systems and galaxies, including our own galaxy, the Milky Way. And **within** galaxies we find our more familiar centers of gravity. Galaxies have their **own** centers of gravity and of galactic rotation. So do individual **stars** such as our sun, whose gravitational force enables us to situate the **Earth** (and ourselves) within the solar system.

Thus we can talk about the **table** being in the room on Earth, rotating with the Earth in its daily rotation, revolving around the sun. The **sun** in its turn is changing its place in our galaxy, and our galaxy too is changing its place, as it participates in the cosmic expansion -- all carrying our table along with them. In this way a center of galactic expansion, plus all of these local centers of gravity, provide the "primary motionless" referents in terms of which we still speak of places in our universe.

4. The Concept of Space

Problems relating to the concept of place still remain, and to address them we must now return to the concept of **space**. Earlier we said that space is a **mathematical** concept, and that is certainly true. But Aristotle considered space a **physical** concept also, one that could be studied by the natural philosopher independently of the mathematician. So let us look briefly at this physical concept.

For Aristotle and St. Thomas space was thought of as an interval or a **distance**. **Real** space, for them, would **not** be identified with the **quantity** of a body, but it is closely connected with that quantity. The essential element in **quantity** is that it designates an ordering of **parts** according to their position in a whole. Immediately flowing from this order are relationships of **closeness** and **distance** of these parts, which can be discerned in the three **dimensions** of length, breadth, and depth. Some **parts** are immediately **close** to each other, whereas other parts are **distant** from each other. Again, by reason of its quantity, one **body** can be **near** to or **far** from another body, by reason of their positioning.

These real relations of distance can be considered in two ways. They can be considered **within** the same quantity, either from one extreme to the other or from one part to another that is closer to or farther from it. This we may be refer to as an internal distance or as **internal space**, the space within the body. The relations can also be considered as a distance **from** one body **to** another, or from one quantity to another. This is external distance or **external space**, that outside the bodies, but between them. **Fig. 5.3**, in the diagram on the left, illustrates these two types of space, and they present no difficulty.

The diagram on the right side of Fig. 5.3 is of interest for its relation to Aristotle's **definition** of place. In examining the **genus** of place, Aristotle raised the question whether **external space**, as we have just defined it, could be used as place's genus. He rejected this possibility for the reason shown in the diagram. The diagram shows a bob suspended from a ceiling and contained within two **possible containers**. Changing the containers would change the **space** within which the bob is located, but it would not change the **place** of the bob, as we have defined it. In fact, an infinite number of containers could be situated around the bob, thus creating an **infinite** number of spaces, but not one would determine the precise location of the bob.

By way of opposition to the real spaces we have been discussing, it is possible to conceive an **imaginary space**. An imaginary space may be defined as the relation of distance between a **real** object and an **imagined** object that is non-existent. It could also be a relation of distance between **two** imagined objects, both of which are non-existent. For example, the universe as we now know it has a **finite** size determined by the limit of its present expansion. It is possible to imagine a space beyond that **limit**, where nothing exists. This would be our **projection** beyond what exists. It would not count as **real** but as **imagined** space, a "being of reason."

To return now to the **mathematical** concept of space, this is similar to imaginary space in that it exists in the imagination of the mathematician. It is different from imaginary space in that it is the object of the science of geometry, obtained by abstraction from sensible matter, as we described in our first lecture. In his thought processes the mathematician employs the second degree of abstraction, different from the first degree of abstraction used by the natural philosopher. Mathematical abstraction **leaves aside** all sensible qualities and natures as found in the physical world, and so arrives at pure extension, abstractly considered. Mathematical space **is** this pure extension, an **ens quantum** or quantified being, very different from the **ens mobile** or moveable being we study in natural philosophy. **Physical** space, on the other hand, is the space filled by natural bodies, where the concept of place is also applicable. It has a decided advantage over mathematical space in that it can take account of the natures of those bodies, which mathematical space does not.

5. Voids and Vacuums

In conjunction with the concept of space the question arises whether it is possible for there to be a **space** in the universe that is **absolutely empty**, a space devoid of any being whatever. This is the problem of the void or the **vacuum**, which has been discussed by philosophers since the time of Democritus. It is easy, of course, to imagine a space that lacks all being, and this may well be the source of Democritus's conviction that both **being** and **non-being** are necessary principles of nature. He saw "being" as **atoms** and "non-being" as the **void**. He held that both atoms and the void are necessary to explain **motion**, for without the void his atoms would have no place to move. All of this he proposed **speculatively**, for he had no empirical evidence to support either atoms or a void. Aristotle opposed this teaching of Democritus, but likewise on speculative grounds.

In the present day much more is **known** about atoms and vacuums, and the argument can move to a higher level. As in the case of **space**, where distinctions had to be made as to the types of space being considered, so in the case of voids or vacuums a few **distinctions** will be helpful in delineating the state of the question.

Aristotle proposed a basic distinction that is still pertinent to our discussion. This is the difference between a **separated** void or vacuum, that is, a space or vacuum outside the universe and thus separated from it, and an **interior** or **interstitial** void or vacuum, that found in interstices or intervals between the parts of bodies, as in Democritus's atomic hypothesis. Aristotle's arguments were directed against both types of void.

As to the separated vacuum, one can argue that the universe is actually **finite**, although motions in it may be unbounded or unlimited. This was true of motions in a circle in the Euclidean space of the Ptolemaic universe, and it is also true of many motions in the **hyperspaces** of modern cosmologies. Again, the notion of a **center** of gravity in the Ptolemaic system rules at an infinite universe, since an infinite physical body cannot **have** a center. The same argument applies to a **center** of galactic recession in the Big Bang theory, and for the same reason.

But if the physical universe is **finite** or limited in extension, this means that there is nothing physically **real** existing beyond and outside its limits. This does not prevent us from projecting, beyond the universe we now know, a **possible** space in regions we may conceive in our imaginations. But this is not the physical space we have just explained, but rather what we have already identified as **imaginary** space. Imaginary space is a being of reason, an **ens rationis** or construct of the mind, although it does have a foundation in reality.

On the question of **interior** voids or vacuums, those in the **interstices** of physical bodies, it is helpful to make a distinction between a **perfect** void, a place in which **nothing** exists, and an **imperfect** void, one in which **something** exists, though in a rarified or aetherial state. There is no objection nowadays to the existence of imperfect vacuums, since it is universally admitted that such voids exist. We talk routinely about vacuum tubes and vacuum cleaners, and we know that physicists are trying to produce ever more perfect vacuums. So we need not be concerned with **imperfect** vacuums since they are not relevant to the problem of the void.

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As to a **perfect** vacuum in the sense of "a place in which nothing exists," this implies a contradiction. A place, by its very definition, is always the place of **something**, so if it contains nothing, it is not a place. This argument seems to be confirmed by the findings of modern science, which increasingly question the possibility of a **perfect** void in the universe. These arise from both relativity theory and quantum theory, with their empirical confirmations.

The general theory of relativity, for example, with its notion of **space-time**, implies that so-called empty space is filled with this hybrid entity that is the **cause** of gravitational phenomena, and therefore does not qualify as a non-existent. Again, quantum electrodynamics proposes that there is a "quantum vacuum" that "fluctuates," and in so doing **produces** subatomic particles that interact with other matter. If the quantum vacuum produces particles, it cannot be **simply** nothing. And finally the Big Bang theory has recently been confirmed by the discovery of a residual **energy field** known as "cosmic radiation background." This is an **electromagnetic** field that extends all the way back to the first moments of the universe and is pervasive throughout its extent. It is found in the **interiors** of atoms, no less than in **intergalactic** space. And either this field requires a medium, analogous to Aristotle's **aether**, or it **is** the medium, which may be aether by a different name.

6. The Concept of Time

We turn now to the concept of **time**. Earlier we said that place and time are **measures**. Place is the measure of the moveable object, that is, the natural **body**, and time is the measure of **motion**, the proper accident of the natural body. It now remains to explain precisely **how**, and in what sense, time is the

measure of motion.

Time is easily associated with motion, and this has led some to think that time is the **same** thing as motion. That this cannot be so is seen from the fact that motions are **particular** and of different types, whereas time is physically **universal** and many motions can take place at the same time. Again, unlike motion, which can be fast or slow, time is **uniform** in its passage. Therefore time **cannot** be the same thing as motion.

On the other hand, the **awareness** of time is very much **connected** with the awareness of motion. We can easily verify this phenomenon for ourselves. If we sense a changing scene with objects in motion, we immediately connect its changing with the **passage** of time. And if we are alone, say in a dark room where we can see **no** motion, it is more difficult to note that passage. But if we have a **succession** of thoughts or images in our imagination, we become aware that time is passing. Thus there is clearly some kind of **link** between time and motion.

Aristotle provided an insight into what that link might be by stating that time is the **number** of motion. Precisely what he means by "number" in this context requires explanation. For example, consider the person in the dark room who has a **succession** of thoughts or images, and is able to reflect on them. The person then becomes aware that there was a **moment**, a "now," in which one thought occurred, and then a **different** moment, another "now," in which a second thought occurred. This situation is diagramed in **Fig. 5.4,** first by the horizontal line on the left and then by the vertical line on the right.

The horizontal line shows two "**now's**," one labeled "first" and the other "second." These may be taken to indicate the two moments in which the person in the dark room was aware of the succession of images. The **interval** between those two "now's" then represents the person's awareness of the **passage** of time.

Alternatively, the **horizontal** line may be taken to plot the **flight** of the bird we discussed in our last lecture. The two "now's" stand for the **moments** when the bird was first "here" and then "there." The **interval** between the two indicates the **time** it took for the bird to fly from here to there.

The **vertical** line on the right represents a similar example, that of heating the water, from our last lecture. Here again there are **two** "now's," one, say, representing the water when it was at 27^{o} C., the other when the water was at 65^{o} C. It took **time** to heat the water, and the passage of this **time** is represented by the interval along the vertical line between the two "now's."

There is still **more** to Aristotle's definition of time. In its complete form the definition reads: **Time is the number of motion according to before and**

after. "Number" is frequently translated as "**measure,**" and so an alternate definition reads" "Time is the **measure** of motion according to before and after." The "**according to before and after**" we have added is a literal translation of Aristotle's text, which in Latin reads *secundum prius et posterius*. The phrase is essential to our understanding of the concept of time.

To what do the "**before**" and "**after**" refer? They refer primarily to the **interval** that is traversed in the various motions being measured, and additionally, to the **direction** in which this interval or distance is being traversed. This is easiest to see in the flight of the bird. Let us say, as before, that the bird is flying **from** a tree **to** a church steeple. And let the "here" of the **first** "now" be when it is leaving the tree, and the "there" of the **second** "now"when it is arriving at the steeple. The "before and after" of the time is now dictated by the distance that has to be traversed and the direction in which the bird goes. In this case "**leaving** the tree" has to be the "before" and the "**arriving** at the steeple" has to be the "after." And the numbering of the two "now's" in **this** order has to be what defines the **time** of the bird's flight.

The same example could be adduced for the heating of the water. In this case the water at 27^{o} would be the **first** "now" and the water at 65^{o} would be the **second** "now." If the water is to be heating, the 27^{o} obviously **has to be** the "before" and the 65^{o} the "after," for this is what is **meant** by its heating. In both the flying and the heating, therefore, the "before" and "after" are dictated by the distance traversed and the direction of the traversal, and these serve to determine the **flow** of time that elapses in each case.

7. The Continuum

One further point has to be made, and this is that **time**, like **motion**, is a continuum. We have used the term before, and have said that time and motion are "**flowing**" continuums. It now remains to explain first what a continuum is, and then what is peculiar about continuums that are "flowing."

The **continuum** is one of the species of quantity, the other being **number**, which is usually thought of as **discrete** quantity. The opposite of this, **continuous** quantity, is best seen in the **extension** or magnitude found in the lengths of lines, surfaces, and bodies. Both numbers and lengths are composed of **parts**, but in different ways. Numbers, and here I mean positive whole integers, are composed of **units** as parts, and we employ these units when calculating with them in a digital way. For Aristotle, the unit or "one" is **not** a number, but it is a **principle** of number. In a literal sense "number" signifies a plurality. (If you held only one apple in your hand, you would not say that you were holding a **number** of apples.) The **parts** of a continuum are more difficult to specify. One way of approaching a definition is to oppose **continuous** length to another type of length that also constitutes extension, which may be called **contiguous** length. successive; adjacent; bordering; touching, kê nhau, tiep giap, giap nhau

Suppose I have **five blocks** and put them together so that they are touching end to end and make up a length of, say, five inches. The end of one block is **not** the beginning of another block, since each block has its **own** ends. This is an example of a **contiguous** length. The word "contiguous" means **touching**, and the ends of the blocks are different but touching each other. Now contrast this with a line segment that is five inches long, along which we designate points at one-inch intervals. These one-inch intervals are the **parts** of the line, since they make up the **length** of the line. The parts are joined at the **points** we have designated, and these points are different from the ends of the blocks. Each point **ends** one line segment and at the same time it **begins** another line segment. On this account the line is said to be **continuous**. The example provides our **first** definition of a continuum, namely, a continuum is a quantity whose parts share a **common boundary**, or whose boundaries are one.

Another definition is based on to the **divisibility** of the continuum. I can take the five blocks apart, and that is as far as I can go in dividing up a **contiguous** quantity. If I have a line segment that is five inches long, on the other hand, I can designate five parts of the line, as I have already done, but alternatively I can **divide** the segment in **half**, and then in **half** again, and then in **half** again, and I can do that *ad infinitum*. Thus we have the **second** definition of the continuum, namely, a continuum is a quantity that is divisible into parts that are **always** further divisible.

From this definition one can see that a continuum cannot be composed **entirely** of indivisibles. In dividing a line segment, one will never come to **points**. Put another way, a line segment cannot be **made up** entirely of points. I say "entirely," because the line segment is terminated at both **ends** by points, and there are points **within** the line that "tie together" the various parts of the segment, as many as one wishes to designate.

The examples I have been giving are taken from a **mathematical** continuum, because this is easier for us to understand. There are also **physical** continuums, an example of which is the natural **body**. Like the line segment, the natural body is a finite **whole** and a unit, and it also has **parts**, but unlike the line it is composed of **sensible** matter, not **imaginable** or intelligible matter. Like the mathematical continuum, the physical continuum can be divided to infinity in the **imagination**. When considered physically, sensible matter is **heterogeneous** and so has different qualities in its various parts. A natural body can also be divided by a physical **cause**, but here a difference manifests itself. A piece of lead, for example, can be divided into **smaller** pieces of lead. But then a question arises: Are all the **parts** of lead lead, in the same way that all the parts of line segments are line segments?

The answer would seem to be "no." Water, for example, can be broken down into smaller and smaller parts, but a point will ultimately be reached where the part is **no longer** water but something else, say, oxygen or hydrogen. This accords with the Aristotelian teaching that there are natural **minimums**, that is, minimal extensions under which particular natures cannot exist. This is obvious in the case of **living** substances, since squirrels cannot be as small as cockroaches. It is true of inorganic substances also. We now know that **molecules** are the natural minimums of chemical compounds and that **atoms** are the natural minimums of chemical elements. Physical bodies can be divided **physically** (and chemically) down to their natural minimums. Beyond this, if a further division is effected, that particular nature will no longer persist but will be **replaced** by a different one.

8. The Existence of Time and Motion

Natural bodies are physical continuums, and these have a quasi stable, permanent **existence**. The two other physical continuums we have been considering, time and motion, do **not** exist in this way, and so are referred to as **transient** or "flowing" continuums. Earlier we have said that all the parts of a permanent continuum exist **together** and at the same time, whereas the parts of a flowing continuum do not. Precisely how the parts of time and motion **do exist** poses a problem, which now attracts our attention.

From our preceding discussion we know that continuums in general are not composed of indivisibles like points as their **elements**, but of **parts** that are in turn continuums. These partial continuums are joined together, however, by **indivisibles**, which have the function of **terminating** but **continuing** the parts they join. How they can do this is what I shall now explain.

We have seen that time is the **measure** of motion and that time and motion are closely associated. It is easier to understand the **parts** of time and **how** they are joined, so let us start with that. As illustrated in the upper portion of **Fig. 5.5**, the parts of time are commonly regarded as the **past** and the **future**. The past and the future are joined by the **present**, which is the moment "now." This moment is actually the indivisible of time. If we compare the flow of time to a line, the "now" is a point that **ends** the part of the line corresponding to the past and **begins** the part of the line corresponding to the future. Thus the "now" is an indivisible that **joins** the past with the future and has the twofold function of **terminating** the past and **originating** the future. This is precisely what we said is the role of indivisibles in the continuum generally.

Now consider this. The past **is** no longer, and the future is **not** yet. There is a sense, it would seem, that the past has passed out of existence and the future has not yet come into existence. What then can we say about the **existence** of time, if both of its parts are non-existent? We propose that time is not existent and real by reason of its **parts**, that is, the past and the future, but it is real and existent by reason of its **indivisible**, the "now." In ordinary speech, of course, we do not stress this **point-like** understanding of "now." We tend to spread it out, as it were, and say it is now 1999, or it is now January, or it is now Thursday, or it is now twelve o'clock. In each case we group a **little** of the past and the future together with the instant that is "now." This illustrates graphically how the "now" **gives** reality and existence to the past and the future, even though neither exists in the way the natural body exists.

The parts of **motion** in a flowing continuum are more difficult to describe. Let me begin by saying that motion is a **successive** continuum. A successive continuum is composed of **parts** that are continuous. Since every motion is a "coming to be," successive motion is a quasi-extended "coming to be" made up of partial "coming to be's" that are **joined** together. They are joined by what I shall call "**intermediate instants**." "Intermediate instants" are the indivisibles of motion, analogous to the "now's" of time, and they are what tie the partial "coming to be's" together. They give reality and existence to the partial "coming to be's" in much the same way as the "now" of time give reality and existence to the past and the future.

Let us now apply this insight to the cases of local motion and heating we have earlier discussed. What is real about the flight of the bird? We can examine that question only while the bird is actually flying, and, of course, flight is a very **transitory** thing. The best way to describe it is by **stopping** it down, as it were, to analyze it in the diagram shown in the lower portion of **Fig. 5.5**. While the bird is in flight, all we have are the **intermediate instants** that signal that part of the flight has been and that part is yet to be. To say that the bird is flying is therefore to say that the bird **has been** flying and **will be** flying. And that will always be at some intermediate instant short of the point at which it ultimately reaches its goal.

To conclude this discussion it is helpful to distinguish between time as **duration** and time as a **measure** of motion. As duration, as applied for example to the bird, the bird's time is equated with the bird's **existence**, and this is fully real. As a measure of the bird's flying, however, time is a **formally** a "being of reason," since it involves the activity of **mind** and **memory** putting the parts of time together to see them as enduring. Yet **materially** and **fundamentally** the time of the flight is as real as the **motion** that is taking place and the **distance** that is being traversed. If there were **no** mind and memory to consider motion and time, would the two still **exist**? In such a circumstance Aristotle would concede them only a sort of **imperfect** existence, since he thought that mind was necessary to confer on them existence in a **formal** sense. But fundamentally they exist to the extent that the sensible continuum exists, and that is sufficient to warrant their consideration by the philosopher of nature.

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FIGURES

Fig. 5.1 The Definition of Place

Fig. 5.2 The Concentric Spheres of Aristotle's Universe

Fig. 5.3 Types of Space

Fig. 5.4 The Nature of Time

Fig. 5.5 The Existence of Time and Motion

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International Catholic University

Philosophy of Nature

6th Lecture: Nature's First Unmoved Mover

- 1. Aquinas's *Prima Via*
- 2. The Motor Causality Principle
- 3. Validity in the Present Day
- 4. Three Instances of Local Motion
- 5. Efficient and Material Causality
- 6. Aquinas's Own Objection
- 7. Nature's First Unmoved Mover

In previous lectures we have covered the basic concepts of the philosophy of nature, matter and form, nature and causality, motion, place and time, and the continuum. Now we move to the most difficult part of the discipline, namely, that concerned with the proof for the existence of a first unmoved mover. What we shall say about this presumes that you have mastered all of the material treated thus far, that you understand it to the point where you can put the concepts we have explained to practical use. This is not a very realistic expectation. Our situation is similar to that of a teacher who has explained to the class a few ideas behind the calculus and then expects the students to solve problems with its use. On the other hand, even if at this stage you may not be able to grasp the full force of the proof, you probably will appreciate obtaining an overview of the arguments on which it is based. That is the most we can reasonably expect from this lecture. I hope mainly to lay the groundwork on which you can build in your later studies, and perhaps throughout your life.

As in previous lectures we will be tracing the main outlines of Aristotle's thought as found in his *Physics*, now mainly Books 7 and 8. But we shall also be getting help from St. Thomas Aquinas, more than in earlier lectures. We shall make use of Aquinas's commentary on these books as well as in his theological writings.

1. Aquinas's *Prima Via*

St. Thomas's proofs for the existence of God, called the "five ways," are found at the beginning of the First Part of his *Summa theologiae*. All five of these "ways" he proposes as proofs from effect to cause, that is, as *a posteriori* demonstrations. Each proof involves four steps. I should note that I am using graphical aids throughout these lectures. They are available to those taking the course for credit. If you have these, the four steps are shown in **Fig. 6.1**. These are that 1) an observational datum exists; 2) this datum is an effect; 3) this effect demands a proper cause; and 4) therefore the proper cause exists. The datum St. Thomas exemplifies in five different ways, namely, as a) movement; b) causal efficacy; c) contingency; d) degrees of perfection; and e) order -- all observable in the universe. These lead respectively to the following characterizations of the proper cause that terminates each of the "ways": a) a First Unmoved Mover; b) a First Uncaused Cause; c) a Necessary Being; d) a Most Perfect Being; and e) a Supreme Intelligence or Supreme Ordering Principle. All of these are ways of characterizing God, and thus the proofs, both individually and collectively, conclude to the existence of God.

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If these "five ways" the *prima via* or first way is the one based most directly on Aristotle's *Physics*, that is, the proof for the existence of nature's first unmoved mover. This proof may be paraphrased as shown in **Fig. 6.2**:

> It is an evident fact that some things in the universe are in movement. But whatever is in movement is dependent on something extrinsic to itself, for nothing that moves can be the complete and adequate explanation of its own motion, and so it must be moved by another. But if the mover that moves the thing in motion is itself moved, then it is necessary that it be moved by another, and it in turn by another, and so on. In such a chain of moved movers actually moving, however, regress to infinity is impossible. For if the chain extend to infinity, then there would not be any first mover actually moving, and since none of the intermediate movers move except insofar as they are moved by the first mover, none of the other movers would move either. Therefore it is necessary to come to some first mover that is moved by no other. This is the First Unmoved Mover, whom everyone understands to be God.

The argument, as commonly understood by Thomists, involves essentially subordinate chains of movers and moveds and concludes to the existence of a mover that itself does not undergo motion, and so is incorporeal and immaterial.

St. Thomas exemplifies the key principle in this argument, namely, whatever is moved must be moved by another, with the case of fire heating wood. Fire, which is actually hot, causes wood, which is able to be hot, to become actually hot. The same thing, he argues, cannot be actually hot and potentially hot at the same time, though there is nothing to prevent its being actually cold and potentially hot. That explains why wood cannot heat itself, but requires an external mover, and ultimately a first immaterial mover, for its heating to occur.

Observe that Aquinas does not use local motion for his example: potency and act are easy enough to see in the case of heating, whereas these two concepts are somewhat difficult to identify in the case of local motion. Note that we have followed a similar procedure in previous lectures, where we have exemplified movement by heating rather than by local motion. Let us now return to that example of heating, for it offers us the opportunity to expand the application somewhat and show how it can provide an insight into a subordinate chain of movers and moveds.

Fig. 6.3 shows the case we have previously treated, fire or a flame in the process of actually heating water (Fig. 4.3). But now we have extended the example, as shown on the right of the diagram, to consider also the air **above** the water that is being heated. In so doing we now have a chain of movers and moveds as illustrated on the left of the diagram: At the top, the fire heats (action is in the agent). In the middle, the fire heats the water (action is in the agent, reception is in the recipient), but the heating (the motion we are analyzing) is not in the fire but it is in the water. At the bottom, the water that is heated by the fire is in turn heating the air above the water. The fire is still an agent, the water is both a recipient and an agent, and the air is a recipient. The fire is a mover, the water is a moved mover, and the air is simply a moved, unless we wish to have it heating the thermometer or some other object. The point is that we cannot go to infinity in a series of moved movers. Without the fire the water would not be heated, nor would the water be a heater, nor would the air be heated, nor would the air be a heater, and so on. In a series of moved movers, there must always be a first.

2. The Motor Causality Principle

At this point I return to Aristotle's *Physics* to examine an alternative proof of the motor causality principle, "Whatever is moved is moved by another." This is given in the seventh book, and it is of interest because it specifically addresses the problem of causality in local motion. St. Thomas comments on this argument and evaluates it as a strict demonstration, indeed, as a demonstration *propter quid*. Aristotle's proof is based on the divisibility of the continuum, and may be paraphrased as shown in **Fig. 6.4**:

> It seems obvious that everything in motion is necessarily moved by some thing. Yet there are cases where the source of the motion seems to be within the object moved, and thus the possibility arises

> that the object moves itself. If it can be shown, however, that the object stops because some other thing stops, this will count as evidence that the object is not moved primarily and essentially by itself, but is being moved by another thing. So, let the object moved be a body AB, and since as a body it is divisible, let it be divided at C.
>
> [diagram]. Now assume that the part CB stops, and then the whole AB must stop also. If AB does not stop, then assume that it is in motion. In this case, if part CB continues at rest it is possible that part AB be in motion. Should this be so, however, AB could not be in motion primarily and essentially, although it might be moved through a part or only accidentally. Since what is of concern here, however, is an object that is in motion primarily and essentially, in this respect it must be held that the whole AB stops when something else stops, namely, its part CB. Therefore it is being moved by another.

The force of this proof is very difficult to grasp at first reading. It involves what may be called the "stopping thesis," namely, that if a whole stops because a part stops, the whole must be moved by another. This thesis has been disputed, accepted by some, rejected by others, from Galen in the second century all the way to Anthony Kenny in our own day. But Aquinas commented on this passage also, and regarded the argument as a demonstraton *propter quid*, "for," he writes, "it contains the reason why it is impossible for a moveable object to move itself." The reason St. Thomas gives is cryptic:

> There cannot be a moveable object whose motion does not depend on its parts; just as if I were to show that a divisible thing cannot be the first being, because the being of whatever is divisible depends on its parts. And thus this conditional is true: "If a part is not moved, the whole is not moved," just as this conditional is true: "If a part is not, the whole is not."

đầy đủ chi tiết

We do not have time to reflect on this argument at length. Suffice it to mention that its middle term is the quantitative divisibility of the moveable object, and it is perfectly general. It applies not only to the fall of a heavy body and to projectile motion, but to the growth of a plant, the flight of a bird, and the explosion of a star in the depths of space. None of these divisible objects completely and primarily initiates its own motion, and thus each must be moved, in some way, by another.

Since this particular proof makes use of divisibility it can be put in quantitative terms, and this makes it easier for one to grasp why an infinite regress of moved movers is impossible. Assuming that the falling object must be moved by another, either the mover that moves it directly is itself unmoved, and hence immaterial (which is a way Sir Isaac Newton thought gravitational motion could be understood), or the mover is moved locally by another.

The second alternative here sets up the possibility of a regress to infinity. But this is impossible, for should one be able to go to infinity in movers that are moved locally, an infinite length would have to be moved in a finite time. To see this, all one need do is reflect on the facts: 1) that whatever is moved locally must be a body and hence must be divisible; and 2) that an infinite number of such bodies is equivalent to a single body of infinite length, since movers cannot move unless they are either contiguous or continuous with the things moved. But it is impossible for an infinite length to be moved in a finite time, and thus it is impossible to regress to infinity in local motions. Therefore, at some point along the line one must come to an immaterial mover, and ultimately to a First Unmoved Mover, when trying to explain any particular case of local motion.

3. Validity in the Present Day

Anthony Kenny rejected St. Thomas's "five ways" because he thought they were too embedded in medieval cosmology to have any relevance in the present day. With regard to the medieval world view, it is true that St. Thomas took the universe to be structured generally along the lines of Aristotle's *On the Heavens*, in Latin the *De caelo*. And if one attempts to instantiate the "first way," as Kenny did, by tracing lines of causality from the terrestrial or sublunar region through a long series of internesting spheres to the *primum mobile* or outermost sphere, one is tempted to identify Thomas's God with Aristotle's *Primum Movens Immobile* and locate him at the periphery of the universe.

Not only Kenny, but many Thomists throughout the centuries have followed precisely this line of thought. That is why they tend to exemplify Aquinas's idea of an essentially subordinated series of movers with mechanical linkages, any one of which moves only because the previous one has moved it. This lends itself to convincing arguments, such as that behind the question: Does lengthening the handle of a paintbrush, even to infinity, make it any more capable of painting by itself?

thích hợp với, có thể dùng làm

But a difficulty is latent here that we must face. For Aristotle and St. Thomas actions were transmitted from agent to recipient instantaneously, just as they thought that light from the sun illuminated the earth's whole hemisphere in an instant. They were unaware of any time lapses that might be involved in impulses that are transmitted physically from one object (or part of an object) to another. Now we know that physical influences take time to travel, and this fact has important consequences for the proof from motion. If the essentially subordinated series of movers and moveds is likened to the fall of dominoes, the fall of the last domino could be temporally quite distant from that of the first.

And if one applies this line of thought to the *prima via*, one could interpret this to hold that the argument does not prove that God exists here and now. It proves only that he existed some time ago -- perhaps a very long time ago, say, at the Big Bang some fifteen billion years into the distant past.

Clearly this is not what St. Thomas had in mind. As he understood his own arguments, God is not situated either at the spatial or at the temporal limit of the universe, but is present everywhere within it, wherever nature or humans act to initiate any causal action whatever. That is why I prefer to formulate the *prima via* along the lines proposed by Aquinas in his *Summa contra Gentiles* over that in his *Summa theologiae*.

In the *Contra Gentiles* St. Thomas explicitly sets up the regress in a series of alternatives. An object that is in local motion, say, a falling body, is moved by a mover that either is unmoved or is moved by another. If unmoved, one has already reached the immaterial order. If moved, then its mover in turn either is unmoved or moved by another. If unmoved, one again has reached an immaterial mover. If moved, the two alternatives again present themselves.

Note that at each point, in this way of formulating the argument, the investigator is invited to entertain the possibility of God's direct presence in a local region. One need not postpone his action either temporally or locally by removing it to the recesses of the universe. We might be tempted to such postponement if we entered immediately into the discussion of long series of moved movers, as the argument presented in the *Summa theologiae* seems to invite us to do.

Using techniques of this kind, we might be able to show that Newtonian or classical mechanics presents no obstacle to understanding St. Thomas's *prima via* or his other proofs. But if Newton's antinomies are thus dissolved, what about more recent science as seen in quantum theory and theories of relativity? I would say that these are even more easily reconciled with Thomistic proofs for God's existence than is Newtonian science. But here the philosophy of science that one embraces becomes critical in accepting or rejecting the reconciliation. The precise point is how to interpret such technical terms as "force," "field," "potential," "energy," and "mass," to say nothing of compound terms such as "mass-energy," "space-time," and "wave-particle." Through the use of such terms I suspect that we have come to regard problems relating to local motion as already solved in such a way as no longer to require a motor causality principle. We are disposed to do this, I have come to think, because we absorb motor causality into such technical terms as these. Thus we effectively terminate the argument before it can be started and so insulate it from philosophical inquiry as to nullify its value as a starting point in any search for transcendence.

The motor causality principle, "Whatever is in motion is moved by another," is particularly difficult for many people to accept when applied to local motion because they think that such application has been invalidated by Newton's three laws of motion. This is not the case, but because it is commonly believed to be so, I shall here examine in some detail how the principle may be applied to this type of movement.

4. Three Instances of Local Motion

Let me illustrate the situation by taking object AB, a divisible body, and instantiating it in the different ways shown in **Fig. 6.5**. These are three in number: 1) as a block of wood; 2) as a mechanical mouse; and 3) as a live mouse. In each case I am interested in the local motion of body AB, a translational motion from here to there.

The first case, though the simplest to visualize, turns out to be conceptually the most difficult. I wish to explain the motor causality involved when the block of wood moves, and again in three different ways: a) when I push it; b) when I throw it; and c) when I allow it to fall to the ground.

The other two cases, those of the mouse, whether mechanical or alive, are less difficult, because the mouse rather obviously moves itself, whereas the block of wood's claim to being a self-mover is not at all obvious. Let us start therefore with the mouse, and inquire into how its motion can enlighten us on the principle, "Every thing in motion is moved by some thing."

The live mouse may be regarded simply as a block of wood, AB, shown as made up of parts D, E, and F in Fig. 6.5a. Let F denominate the part or parts that seem to move as a whole, and E the quantitative parts that do the moving when the whole moves. I do not intend to enter into the physiology of mice, so I will be content to identify E as the brain, the heart, the muscles, and the legs, to all of which we ascribe the mouse's motor activity. Aside from these parts, however, Aristotelians will insist on yet another mover, D. Unlike the other two parts, D is not simply a quantitative part. It is a qualitative part, or more precisely a power part, the motor power of an animal's natural form, which we modeled in our fourth lecture (Fig. 4.2). Another term for the mouse's natural form is "soul." Now, to the extent that the soul or natural form is not a quantitative part, and to the extent that it is separable from the mouse's body, and upon separation results in a dead, or inert, or unmoved mouse, we can say in this instance that the soul is other than the mouse's body. Therefore the body's movement illustrates the principle, "Whatever is in motion is moved by another thing."

For those who have difficulty with the soul concept, let us consider now the mechanical mouse, and for the sake of simplicity, let us conceive it as merely a block of wood, AB, moved by wheels that are made to rotate by a coiled spring or a stretched rubber band. This is now shown in Fig. 6.5b. Wind up this mechanical mouse, place it on a smooth surface, and it too seems to move itself. The case is not dissimilar to that of the live mouse, so let me label the moved part, the block of wood, F, and the moving part, the wheels, E. Perhaps I should include with the wheels the spring or the rubber band, for a further condition is needed for the wheels to move the block of wood. The spring must be coiled, or the rubber band must be stretched, and although the coiling and stretching may introduce a quantitative change in the object coiled or stretched, the resulting modification is more qualitative than it is quantitative. It is difficult to name this qualitative part, which I shall label D, but common usage will let me employ the terms force and energy. We say D moves E and E moves F, in the sense that the force moves the wheels and the wheels move the mouse. Or we say that the mechanical mouse moves as long as there is energy in the spring or in the rubber band, and this energy moves the wheels, which in turn move the mouse. Note how, in this explanation, the concepts of force and energy play the same role as the concept of soul. If one were to inquire whether the case of the mechanical mouse instantiates the motor causality principle, we would have to reply that, to the extent that the force and the energy are different from the body AB, to that extent "Whatever is in motion is moved by another thing.'

These cases have illustrative value, but it seems to me that neither is precisely what Aristotle had in mind when he wrote of a body AB moving primarily and essentially, for both can be traced down to motion "through a part," and through a part (*per partem*) is usually opposed to *primo et per se*, the Latin for "primarily and essentially." The simple block of wood, however, unadorned with wheels, spring, or rubber band, can move *primo* and *per se*, so let us now turn our attention to the simple block, shown in Fig. 6.5c.

First imagine the block AB on a plane surface, and let us examine the case where it moves because I push it. In such a case there is no doubt that whatever is moved is moved by another, and I am that other. Note here, however, that even I can be replaced by the force concept, for my push on the body can be conceived as a mechanical force, and then we say that the block of wood, F, is moved by me as a pusher or by a force, I/E.

Second case: instead of my merely pushing the block of wood along a surface, let me now throw it through the air, as shown in Fig. 6.5d. Consider the thrown block in simple translational motion, and then the whole block and each of its parts move with the same velocity. Now, does this case instantiate the motor causality principle? I threw the block, let there be no doubt about that, and so it would seem that I am the mover. In a general way that may suffice for an answer, but it does not seem to explain how I move the block **after** it has left my hand. Perhaps we should say that I impressed a force, or an impetus, or a momentum on the block of wood, and this serves to explain its motion. Note that, as in the case of the mechanical mouse, explainers such as these are essentially qualitative. So now let us say that the moved body, F, is moved remotely by me, I, now distant from F, but proximately by a qualitative part, D, that inheres in the block, which I conceive as force, energy, or momentum.

Finally, let us consider the case where I do not throw the block of wood but simply remove the support from under it and it drops to the ground, as diagramed in Fig. 6.5e. The block of wood moves, and clearly I do not move it in any essential way, and so again it seems to move itself. But is this actually the case? If we subscribe to the powers model of an inorganic substance we developed in the third lecture, the case is not very different from that of the live mouse. Like the mouse, the wood is a natural body, and it has the power of gravity as part of its nature, just as the live mouse has motor powers as part of its nature. I am the initiating efficient cause of the fall of the block, but once I have removed the support under the block, the block is moved by its own nature, the nature of wood, through its power of gravity. So we would identify the elements involved in the body's fall, as F, the moved quantitative part; D, the moving qualitative part, its power or force of gravity; and myself, I, the initiating mover, who activated a power inherent in the wood as part of its nature.

tán thành

5. Efficient and Material Causality

From this exercise we can gain some idea of how difficult it is to trace the causal agents behind local motion when we resort exclusively to the terminology of modern science. In such a circumstance causal efficacy has to be interpreted through the concepts of force, energy, and momentum. Without such terminology, for example, in the way the proof from motion of an unmoved mover is stated in Aristotle's text or in Aquinas's commentary, we gain some appreciation for the sheer inertness and passivity of the material object as such. The introduction of force and mass-energy in this context enables us to focus attention on elements of efficiency and activity in the material substrate. This focus also provides a ground for suspecting that elements of the divine may be found in matter. But when we absorb motor causality totally into these terms, and regard them as logical constructs that have no reference to the real world apart from a theoretical system of which they form a part, the proof quickly loses its persuasive power. In effect, we suppress any intimation of transcendence that are to be found in the movement of material objects. That is why, for many of our contemporaries, physical arguments for the existence of God are terminated before they start. Or they become so insulated from philosophical inquiry as to nullify their value as valid starting points.

utilize a source of help

In a position to obstruct, hinder, or interfere.

ko xem xet gi den

an idea or a belief that is based on various pieces of evidence which are not always true

cách ly

If we adopt a realist philosophy of science, on the other hand, and particularly if we restore causality to its proper ontological category instead of seeing it as a psychological projection on reality, we can go far in making Aquinas's *prima via*

tra lai; phuc hôi

intelligible to the modern mind. In my view, the primacy of local motion and the divisibility of the material continuum in the world of nature is the essential starting point for this type of argumentation. And that is also to see that, in many proofs, material causality assumes equal importance with efficient causality. Arguments through a material cause, as in the way St. Thomas certifies the proof we sketched earlier involving the "stopping thesis," frequently yield conclusive results when efficient causes prove opaque to our investigations.

not transparen

And yet the action of efficient causes is discernable in the cases we have just discussed despite their use of scientific terminology. Every change in the universe involves local motion, and as such has both inertial and gravitational components. Changes also involve thermal, electromagnetic, chemical, vital, and even psychic energies. When we abandon the so-called clockwork universe, there is less room for essentially subordinated series of movers and modes that work in mechanical fashion. But the same type of subordination is still to be found in the action of fields, and particularly vector fields, even though these imply reference to different kinds of forces and energies than those involved in classical mechanics. By way of example, using the space-time construct of general relativity, every natural or forced motion in the universe is determined by the energies involved in its production. Such motion requires continued specification and determination throughout every instant of its motion (in a time-independent way, following the path of a geodesic), to attain a predetermined goal.

duòng trác dia

di lac dê

To see the full implications of this statement, I digress now on the relationship between God's causality and nature's causality as these bear on problems of local motion. This topic is addressed by St. Thomas himself, in an objection he raises against his own proofs for God's existence, to which I now turn.

co lien quan, quy vao

6. Aquinas's Own Objection

The article in the *Summa theologiae* that explains the five ways is one of the longest in its First Part. It is remarkable that St. Thomas raises only two short objections against this extensive line of argument, now a classic in Western thought. The first, undoubtedly the most difficult, is the existence of evil in the world. But no less easily dismissed is the second, which, beginning with a principle of parsimony similar to Ockham's famous razor, reads as follows:

> Whatever can be effected by a few principles does not require more. But, supposing that God does not exist, everything that goes on in the universe can be fully accounted for by alternate principles -- for natural effects are explained by nature as a cause, and intended effects by human reason and will. Thus there is no need to suppose that God exists.

Setting aside the second alternate principle, we most focus on the first, the alternative posed by nature. If the fall of a heavy object or the flight of a bird is caused by nature, what need is there for God's causality to explain their respective notions?

St. Thomas solves the problem in his reply to the objection, but his solution is too brief to be of much help. He writes simply: "Since nature acts for a definite goal under the direction of a higher agent, things done by nature must also be referred to God as to a first cause." That's it. That is all St. Thomas says. Both nature and God are required to explain the fall of the body and the flight of the bird, but exactly how they are required and how they respectively influence those motions, he leaves us to puzzle out for ourselves.

Fortunately for us, St. Thomas does return to this problem toward the end of the First Part of the *Summa*. This is in question 105, article 5, where he is explaining his teaching on the divine *concursus*, or how God himself is active in every agent cause. The Latin for this is *Deus operatur in omne operante*, literally "God operates in everything operating." Aquinas first distinguishes the four kinds of cause, as we have done in discussing the causality of nature, and then goes on to explain God's action in each, the material cause alone excepted. For our purposes it may suffice to concentrate only on formal causality, for this is what is involved in nature, and gravity, and impetus, all of which are forms that initiate the motions we have been discussing. Of such formal causality, what he writes is shown in **Fig. 6.6**:

> Consider that God moves things to operation not only by applying their forms and powers to work in the way a craftsman applies the axe to cutting, without giving the axe its form; he also gives these forms to created agents and conserves them in being. Thus he is not only the cause of action by way of giving the form that is the principle from which the action proceeds, the way in which the generator is said to be the cause of the movements of heavy and light bodies. He is also the cause as one who conserves these various forms and powers in being, just as the sun is the cause of colors' appearing in that it gives and maintains the light by which they are seen.

Having explained this, St. Thomas then goes on:

> It further follows that God acts **interiorly** in all things, because the form of anything is within it, and the more so the more basic and universal the form is. For all things God is properly the universal cause of *esse* or being, and *esse* is innermost in all things. This is the reason why in Holy Scripture the operations of nature are attributed to God as to one operating within nature itself.

This, then, is how Aquinas sees nature as functioning causally, but as doing so as God's instrument. Matter itself is sluggish and inert. The falling body, precisely as a body and thus divisible into quantitative parts, is radically incapable of moving itself simply in virtue of those parts. The heavy body falls not because it is a body but because it has the nature it has, and because that nature is endowed with characteristic forms and powers through which it is able to initiate activities proper to that nature. More specifically, it falls because there is within it the form or power of gravity, because this form or power is sustained in being by Subsistent Being itself, and because it is activated by secondary causes that themselves act in virtue of the First Uncaused Cause. Nature causes the body's fall, and so there is truly a causality of nature, but God's *concursus* is there along with nature and its powers, sustaining them in being, energizing them, we might say, and enabling them to bring about the effects we attribute to them in everyday life.

Let us return now to the scientific context which we were treating before digressing on these passages in the *Summa*. Obviously the principle "Whatever is moved is moved by another" allows for a variety of interpretations. In the Greek-medieval framework the phrase "by another" was understood to be effected through some type of contact, either mechanical or virtual, whereby the mover exerted a direct influence on the thing moved. In a Newtonian or Einsteinian framework the same phrase is understood in a spatio-temporal or metrical way. It is then interpreted as the action of some type of field or potential that is able to determine precisely the resulting motion.

capable of producing an effect through inherent power or virtue

In either framework, the existential character of motion ultimately requires that the moving object and its powers be sustained throughout, that is, in the object's "coming to be" no less than in its "being" or *esse*, at every moment of its existence. Here the essential dependence of any existent on Subsistent Being Itself, whether transitory as in the case of a motion or stable in the case of an object, cannot be dispensed with. The problem of the scientist is that of discerning the secondary causes, the detailed processes through which this existential influence is channeled in the daily workings of nature.

For St. Thomas Aquinas there is an intimate link between the causality of God and the causality of nature. Aristotle's First Mover may have been located at the periphery of the ultimate sphere, but Aquinas's God certainly is not. He is **everywhere** by his power and his presence, no less in the remote depths of space than in the microstructure of matter. Man has his artifacts, and in the technological age in which we live we all rejoice in the remarkable feats of intelligence he can perform through their use. In Aquinas's view, God stands in relation to nature much in the way that man stands in relation to his artifacts. Simply put, nature is God's artifact. Once we understand that, it should not be too difficult to see how God serves as an ultimate explanation in our expanding universe as well as, if not better than, he did in the circumscribed universe of ancient times antiquity and the Middle Ages.

7. Nature's First Unmoved Mover

Finally, we return to our philosophy of nature for a final reflection on nature's First Unmoved Mover. In natural philosophy the first cause of motion is considered only insofar as it is necessary to understand motion in natural things and to determine whether the primary source of motion is or is not a natural body. A body is something extended and divisible in parts that are in it and thus compose the whole. A body or extended whole is not an independent being, but depends on its parts for its being. A body is dependent also upon its parts for being moved, because motion requires a subject that is extended and divisible into parts. But the first cause of motion is completely independent in action, and hence also in being, because operation follows being, and the manner of acting is consequent upon the manner of being. do, boi , là hau qua cua, là ket qua cua

Therefore, the first cause is **not** a body, and does **not** have parts on which it depends for its being and acting. It is **not** composed of matter and form, **nor** of potency and act. It is **not** capable of being moved or having motion, either by itself or by something else, but it is the **unmoved** mover of other things. Because it is unmoved, it is **not** a temporal being but eternal. Because it is unmoved and incorporeal, it does not cause motion **mechanically**, as one body moves another from without, but rather as **mind** or **intelligence** moves a body with a higher order of action.

outside

It is the proper business of the natural philosopher to seek the causes of motion in natural bodies. In order to understand his subject he must **not** rest content with some intermediate mover, nor with all intermediate movers -- supposing that they could all be determined -- but must seek the **first** cause of motion. Finally, and this is most important, it is only after one knows, through the study of nature, that there exists a kind of being that is not mobile or corporeal, but immobile and incorporeal, that one can show the need for a science beyond the philosophy of nature, the science of metaphysics. After we have covered the *Phusika*, as the Greeks might say, we have opened the path to a possible *Metá-phusika*, a science "beyond *Physics*." But to pursue that path would take us far beyond the modest undertaking in which we have been engaged throughout these lectures, the philosophical study of the world of nature.

FIGURES

Fig. 6.1 Proofs for God's Existence

Fig. 6.2 Aquinas's *Prima Via* or First Way

Fig. 6.3 A Subordinated Chain of Movers and Moveds

Fig. 6.4 Aristotle's Proof of the Motor Causality Principle

Fig. 6.5 Three Cases of Local Motion

Fig. 6.6 God's Operation in Nature

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Philosophy of Nature

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Reading Assignments and Review Questions

Modeling = *The Modeling of Nature* (Catholic Univ. Press, 1996), Page Nos.; *Elements* = *The Elements of Philosophy* (Alba House, 1977), Sec. Nos.

Lecture 1: Fundamental Concepts

Readings: *Modeling* -- pp. 118-126 on knowledge, sensation, perception; pp. 131-139 on concepts; pp. 170-173 on sciences; pp. 300-308 on the demonstrative regress; *Elements* -- sec. 2 on logic; sec. 8 on predicables; sec. 9 on categories; sec. 12 on demonstration; sec. 13 on science; sec. 37 on epistemology; sec. 38 on knowledge.

Questions: 1. How would you define knowledge? sense knowledge? intellectual knowledge? 2. What is the difference between a percept and a concept? 3. What is the difference between a real concept and a logical concept? 4. How does natural philosophy differ from mathematics? from metaphysics? 5. How do the concerns of the natural philosopher differ from those of the modern scientist? 6. Identify the two types of demonstration that are involved in the demonstrative regress.

Lecture 2: Nature -- The Inner Dimension

Readings: *Modeling* -- pp. 3-7 on causality; pp. 7-18 on the four causes in nature; pp. 22-31 on the inner dimension, the individual natural body; *Elements* -- sec. 15 on philosophy of nature; sec. 16 on matter and form; sec. 17 on nature; sec. 34 on substance and accidents; sec. 35 on causality and its kinds.

Questions : How would you define natural form? protomatter? 2. Which is more intelligible, natural form or protomatter? Explain. 3. Identify three different meanings of end or final cause. 4. Explain why a thing's nature can be called its "inner dimension." 5. Enumerate the basic constituents of an individual natural body. 6. Give three examples each of substances and accidents that are found in the order of nature.

Lecture 3: Nature's Powers and Natural Kinds

Readings: *Modeling* -- pp. 31-34 on modeling various natures; pp. 134-135 on human cognitive powers; pp. 180-185 on human powers in operation; pp. 38-45 on the elements; pp. 45-73 on modeling inorganic natures. *Elements* -- sec. 24 on sensation and perception; sec. 25 on intellection; secs. 26-27 on appetition and sensitive appetites; sec. 28 on volition; sec. 29 on man; sec. 22 on life and soul.

Questions: 1. Identify the basic powers found in human nature. How may they be represented in a stimulus-response model? 2. How are protomatter and natural form represented in the powers model of an inorganic nature? 3. Compare the Aristotelian model of an inorganic nature with that of the modern physicist. 4. How can the Bohr model of the atom cast light on the function of the natural form in inorganic processes? 5. Contrast the modern chemist's explanation of chemical combination with that of the natural philosopher. 6. Contrast the modern physicist's explanation of radioactivity with that of the natural philosopher.

Lecture 4: Nature's Property -- Motion or Change

Readings: *Modeling* -- pp. 76-97 on plant natures and their activities; pp. 97-113 on animal natures and their activities. *Elements* -- sec. 18 on motion; sec. 66 on philosophy of science; sec. 67 on methodological concepts; sec. 68 on physical sciences.

Questions: 1. How are the activities of plants and animals different from those of inorganic natures? 2. What different meanings are assigned to the terms "motion" or "change" in natural philosophy? 3. What is Aristotle's first definition of motion? 4. Apply the elements of this definition to the heating of water. 5. How is Aristotle's first definition of motion related to his second definition of motion? 6. How does Aristotle define action and reception, and how are both related to motion?

Lecture 5: Nature's Measures -- Place and Time

Readings: *Modeling* -- p. 29 and 62 on quantity as individuating; pp. 29, 136, and 240 on continuous quantity; pp. 239-244 on measurement and metrical concepts. *Elements* -- sec. 19 on place and time; sec. 63 on the philosophy of mathematics; sec. 64 on number and the continuum.

Questions: 1. What is Aristotle's definition of place? 2. In this definition, to what does the expression "primary motionless" refer, in Aristotle's world and in our present universe? 3. What is the concept of space? Is there such a thing as empty space? 4. Explain Aristotle's definition of time and its relationship to motion. 5. Why are time and motion referred to as "flowing continuums"? 6. How can time and motion be said to exist?

Lecture 6: Nature's First Unmoved Mover

Readings: *Modeling* -- pp. 359-363, 406-409 on Newton on the nature and cause of gravity. *Elements* -- sec. 20 on the First Unmoved Mover; sec. 41 on natural theology; sec. 43 on proofs of God's existence; sec. 47 on divine causality.

Questions: 1. What is the basic structure of Aquinas's proofs of God's existence? 2. Outline the elements of Aquinas's "first proof," the *prima via*. 3. What is the motor causality principle? 4. In his commentary on the *Physics* Aquinas offers a demonstration of this principle. Is it based on efficient or material causality? Explain your answer. 5. Give three examples of how the principlecan be verified when applied to movers in local motion. 6. What is Aquinas's objection from nature to his proofs of God's existence, and what is his final resolution of the difficulty?

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